Popular Astronomy.

Vol. XV No. 5. MAY, 1907. Whole No. 145

HOW TO OBTAIN THE POSITION OF A STAR FROM A PHOTOGRAPH.

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

The great numbers of astronomical photographs which are being obtained and the high degree of accuracy with which positions may be determined from them, make it very desirable that the methods of measurement and reduction should be as simple as possible, and very generally known.

A telescope of only six inches aperture and five or six feet focal length is capable of producing photographs from which the positions of stars can be determined with an error of less than one second of arc. This accuracy greatly exceeds that obtainable with a filar micrometer attached to the *same telescope* and equals that of a micrometer observation with a much larger telescope.

The great need of positions of asteroids, stars in the coarse clusters, certain classes of stars in the Milky Way, variables, proper motion stars, etc., opens up a wide and attractive field for moderate sized telescopes. Indeed it is one of the most fruitful fields for those amateurs who have access to engines for measuring the negatives. Work of this nature, if carefully done, is of great and lasting value.

The measurement and reduction of photographs is no more difficult than the reduction of filar micrometer measures and when the positions of a number of objects are to be obtained from a single plate, the photographic method is much the quicker.

I have recently shown how the work of reducing the measures of a photograph may be somewhat simplified.*

In the present paper I shall give all the necessary steps to be taken in the measurement and complete reduction of a photograph, together with a few suggestions as to the choice of comparison stars, methods of measuring, etc. As it is especially intended for those without previous experience, examples will be given. For work where rigorous solutions are not justified, very simple forms of reduction will be explained.

* *L. O. Bulletin* Nos. 102 and 107.

The Measuring Engine.

A few of the more important requirements of a measuring engine intended for the measurement of rectangular coördinates should be noticed.

The machine should be provided with a position-circle for orienting the plate. It should have *two* slides, at right angles to each other for measuring both coördinates simultaneously. Much time is thus saved.

Glass scales are preferable, where measurements are to be made on glass negatives.

The division-errors of the scales can and ought to be very much less than the accidental errors in the positions of the star images to be measured. The errors of the scales may then be ignored, without decreasing the accuracy of the results. The saving in time, by taking such a precaution, is considerable.

If the bisections of the star-images are made with a telescope having a fixed reticle, no troublesome reductions of micrometer readings are involved, and no accuracy is lost.

High-power microscopes having glass reticles ruled with fine divisions, may be used to read the scales with no real loss of accuracy and with great economy of time.

The illumination of the plate to be measured should be such as not to require any change with a change of position of the negative.

The adjustments of a measuring-engine should be carefully tested before doing any work with it. The most important are:

Straightness of the slides.

Parallelism of the plane of rotation of the position-circle and plate, to the slides.

The two slides should be accurately at right angles to each other.

These conditions are usually met by the makers:

A knowledge of the scale-errors is essential.

Measurement of the Plates.

It is assumed that the plate to be measured has been taken with a telescope whose objective was correctly collimated and that the plate was normal to the optical axis, this axis passing as nearly as possible through the center of the plate.

The negative is inserted in the measuring-engine with its film side next to the objective of the setting-telescope.

For the orientation of the negative on the engine two catalogue stars are selected as far apart as possible consistent with good images. It is of practical importance to have them nearly symmetrical with the center of the negative. It is a *convenience* to have them differing just enough in either right ascension or declination, to make the angle between the line joining them and the hour circle or equator appreciable to the eye.

Mistakes in changing the circle to the equator are much less likely to occur if this condition is observed.

The angle between the equator and the line joining the two orientation stars is then determined with sufficient accuracy from their catalogue places,* by the formula

$$\tan u = \frac{\Delta\,\delta}{\Delta\,\alpha}$$

$\Delta\alpha$ being in arc of a great circle.

By a few trials the direction of the orientation-stars may be made parallel to either of the axes of the engine. The circle is then read and after applying the angle u the circle is set to the computed equator of the plate.†

A little care in orienting the plate on the machine is repaid by small residuals for the plate-constant solution, and, in less rigorous work, it renders a complete solution unnecessary. The setting of the plate to the equator may be checked by taking the $\Delta X_0'$ or $\Delta Y_0'$ making an approximate reduction, and comparing the result with the $\Delta\alpha$ or $\Delta\delta$ from the catalogue places.

Before putting the plate in the engine, an ink circle should be drawn around each object to be measured, on the glass side, for the purpose of finding it readily in the observing telescope. A number or letter should be added to facilitate identification.

Five or six catalogue-stars are sufficient to give good plate-constants. More than this number are seldom justified in ordinary work. Three are very often enough.

The more symmetrically the comparison stars are situated about the center of the plate, the stronger will be the resulting plate-constants. It is an advantage to have the stars within 30′ of the center.

---

* It may be pointed out that *mean* places for the beginning of the desired year should be used in the reductions. If the *apparent* place of an object is wanted, the apparent-place reduction may be made in the usual way after its *mean* place has been derived from the photograph.

† If a star has been allowed to trail on the edge of the plate, the position of the equator is at once determined from the trail. If the star has a large declination its trail will be curved appreciably and orientation should be accomplished upon two points equidistant from the center of the plate. It should be noted that orientation from a *trail* gives the *apparent equator* of date.

The measures should then be made, beginning and ending with the unknown object (or one of them) as a check against any accidental displacement of the plate during measurement.

Two settings on each of the objects are usually all that the real accuracy of the photographs justifies.

After all of the objects have been measured, the plate should be rotated 180° and a similar set of measures made in the new position. The mean of these two sets of measures, direct and reversed, eliminates almost, if not all of the personality which every observer has to a greater or less extent.

Before the plate is removed from the engine, the differences between the center of the plate, which is used as origin, and each object should be taken for each position of the plate. The differences resulting from the *direct* measures should be compared with those resulting from the *reversed* measures and any discordances should be investigated at once.

Reduction of the Measures.

To obtain the accurate position of a star on a plate, four constants, beside a knowledge of the refraction, are necessary, *viz.*:

Scale value,

Orientation, and

The right ascension and declination of the "center" of the plate.

Values for the first two constants, as near the true ones as possible, are assumed and corrections obtained by a least square adjustment of the residuals derived from a comparison with catalogue stars.

To obtain the rigorously accurate fundamental point or center it is only necessary to apply the mean of the *proper curvature corrections* to the mean of the right ascensions and declinations of the comparison stars.

Theoretically, the assumed center should agree with the optical axis of the photographic telescope. Any deviation, however, is allowed for by using *curvature corrections* depending upon distances measured from the *point of intersection of the optical axis* on the plate*, as origin.

The adoption of the above center shortens the solution for the remaining two constants by reducing some of the coefficients to zero. A number of simple checks can also be introduced.

Using the point of intersection of the optical axis on the plate, as origin, the coördinates X_0', Y_0', etc., of each star are obtained

* The objective should be adjusted so that the optical axis will intersect the plate at its center.

in turn from the measures of the plate in the sense star minus origin. The *direct* and *reversed* measures are then combined before solution.

The plate measures X_0', Y_0' are converted into X_0 and Y_0 by tables, or otherwise, using the best scale-value available.*

The relations are as follows,

$$X_0 = X_0' \frac{1}{15} s \sec \delta \qquad (1)$$
$$Y_0 = Y_0' s.$$

The true declination of the intersection of the optical axis should be used in making the conversions into X_0; s is the scale value. Tables should be used for the Y_0 conversions, if possible.

The coördinates, C, Q, of the center of gravity of the group of comparison stars are then:

$$C = \frac{X_{oa} + X_{ob} + X_{oc} + \cdots X_{on}}{\nu} \qquad (2)$$
$$Q = \frac{Y_{oa} + Y_{ob} + Y_{oc} + \cdots Y_{on}}{\nu}$$

ν is the number of comparison stars.

We now change our origin of coördinates to this center of gravity of the comparison star system and the coördinates referred to the new origin become X, Y.

The right ascension and declination of this center, C, Q, are now to be determined from the known stars.

The arithmetical mean of the catalogue α and δ of the comparison stars, in the form:

$$c = \frac{\alpha_a + \alpha_b + \alpha_c + \cdots \alpha_n}{\nu} \qquad (3)$$
$$q = \frac{\delta_a + \delta_b + \delta_c + \cdots \delta_n}{\nu}$$

is correct for the *equator* if the center of gravity is also the center of symmetry. For all other cases c, q, will be affected by the corrections for the curvature of the field. These corrections may be computed and applied as follows:

$$c' = c - \frac{[A'']_a + [A'']_b + [A'']_c + \cdots [A'']_n}{\nu} \qquad (4)$$
$$q' = q - \frac{[D'']_a + [D'']_b + [D'']_c + \cdots [D'']_n}{\nu}$$

---

* A very good scale-value may be obtained for a preliminary solution from the $\Delta\delta$ of two widely separated stars. The solution of one or two plates will then furnish a sufficiently good value for future use.

$[A'']_a$, $[D'']_a$, etc., are the sums of all the sensible terms of the curvature corrections, computed by the following formulæ:*

For X_o

$$
\begin{aligned}
A_1'' &= A_1 X_o \, Y_o \\
A_2'' &= A_2 X_o \, Y_o^2 \\
A_3'' &= A_3 X_o^3 \\
A_4'' &= A_4 X_o^3 \, Y_o \\
A_5'' &= A_5 X_o \, Y_o^3 \\
A_6'' &= A_6 X_o^3 \, Y_o^2 \\
A_7'' &= A_7 X_o^5 \\
A_8'' &= A_8 X_o \, Y_o^4
\end{aligned} \qquad (5)
$$

For Y_o

$$
\begin{aligned}
D_1'' &= D_1 \, X_o^2 \\
D_2'' &= D_2 \, X_o^2 \, Y_o \\
D_3'' &= D_3 \, Y_o^3 \\
D_4'' &= D_4 \, X_o^2 \, Y_o^2 \\
D_5'' &= D_5 \, X_o^4 \\
D_6'' &= D_6 \, X_o^4 \, Y_o \\
D_7'' &= D_7 \, X_o^2 \, Y_o^3 \\
D_8'' &= D_8 \, Y_o^5
\end{aligned} \qquad (6)
$$

The auxiliary quantities A_1, etc., D_1, etc., are computed by the following formulæ;

$$
\begin{aligned}
A_1 &= \sin 1'' \tan \delta && [\,4.68557-10] \\
A_2 &= \sin^2 1'' \tan^2 \delta && [\,9.37115-20] \\
A_3 &= -\tfrac{1}{3}\,(15)^2 \sin^2 1'' && [_n1.24621-10] \\
A_4 &= -(15)^2 \sin^3 1'' \tan \delta && [_n6.40890-20] \\
A_5 &= \sin^3 1'' \tan^3 \delta && [\,4.05672-20] \\
A_6 &= -2\,(15)^2 \sin^4 1'' \tan^2 \delta && [_n1.39551-20] \\
A_7 &= \tfrac{1}{5}\,(15)^4 \sin^4 1'' && [\,2.74769-20] \\
A_8 &= \sin^4 1'' \tan^4 \delta && [\,8.74230-30] \\
D_1 &= -\tfrac{1}{4}\,(15)^2 \sin 1'' \sin 2\,\delta && [_n6.43570-10] \; (7) \\
D_2 &= -\tfrac{1}{2}\,(15)^2 \sin^2 1'' && [_n1.42230-10] \\
D_3 &= -\tfrac{1}{3} \sin^2 1'' && [_n8.89403-20] \\
D_4 &= -\tfrac{1}{2}\,(15)^2 \sin^3 1'' \sin^2 \delta \tan \delta && [_n6.10787-20] \\
D_5 &= \tfrac{1}{8}\,(15)^4 \sin^3 1'' \,(3 \sin \delta \cos^3 \delta + \sin^3 \delta \cos \delta) && [\,7.85799-20] \\
D_6 &= \tfrac{3}{8}\,(15)^4 \sin^4 1'' && [\,3.02069-20] \\
D_7 &= \tfrac{1}{2}\,(15)^2 \sin^4 1'' \,(1 - \tan^2 \delta) && [\,0.79345-20] \\
D_8 &= \tfrac{1}{5} \sin^4 1'' && [\,8.04333-30]
\end{aligned}
$$

The logarithms of the constant quantities are given in brackets.

As already noted, δ is the true declination of the intersection of the optical axis on the plate.

---

* It is hoped to publish shortly tables from which the curvature corrections may be obtained directly by interpolation.

The above expansions are accurate to 0″.01 for measured coördinates of 60′ or less, and declinations as high as 75°.

Theoretically two sets of expansions are necessary, one depending upon arguments X_0, Y_0 (for the plate measures), the other upon arguments x, y (for the catalogue places). In practice but one set is necessary and the formulæ have been arranged accordingly.

The values of x, y are next computed from the catalogue places of the stars by the following formulæ:

$$\begin{aligned} x &= \alpha - c' - [A''] \\ y &= \delta - q' - [D''] \end{aligned} \qquad (8)$$

where α and δ are the right ascension and declination of the star.

A comparison of the plate coördinates and of the coördinates derived from the catalogue places yields the residuals n'_x and n_y as follows:

$$\begin{aligned} n'_x &= [X - x + M_x X + N_x Y]\ 15 \cos\delta \\ n_y &= Y - y + M_y X + N_y Y. \end{aligned} \qquad (9)$$

The refraction terms M_x, N_x, M_y, N_y are computed as follows.

$$\begin{aligned} M_x &= k \sin 1'' \,(1 + H^2) \\ N_x &= \tfrac{1}{15}\, k \sin 1'' \,(G - \tan\delta)\, H \sec\delta \\ M_y &= 15\, k \sin 1'' \,(G + \tan\delta)\, H \cos\delta \\ N_y &= k \sin 1'' \,(1 + G^2) \end{aligned} \qquad (10)$$

in which G and H are derived from the following equations:

$$\begin{aligned} &\sin n \sin N = \cos\phi \cos t \\ &\sin n \cos N = \sin\phi \\ &G = \cot(\delta + N) \\ &H = \operatorname{cosec}(\delta + N) \tan t \sin N. \end{aligned} \qquad (11)$$

ϕ is the geographical latitude, t and δ are the *true* hour-angle and declination, respectively, of the origin of coördinates; k is the Besselian constant of refraction. For nearly all cases k may be taken as 1.7681 (logarithmic), which is the value for sea level pressure and a temperature of 55° F. The algebraic signs of the refraction corrections result from the solution.

The equations of condition for the derivation of the corrections to the scale-value p and orientatiou r take the forms;

$$\begin{aligned} \pi p + \rho r + n'_x &= 0 \\ \rho p - \pi r + n_y &= 0 \end{aligned} \qquad (12)$$

where

$$\begin{aligned} \pi &= X\ 15 \cos\delta \\ \rho &= Y \end{aligned} \qquad (13)$$

One or two places are usually dropped in the coefficients π and ρ and restored at the end of the calculation, without loss of accuracy.

The solution of these equations is effected by the following simple formulæ:

$$p = -\frac{[\pi n'_x] + [\rho n_y]}{[\pi\pi] + [\rho\rho]}$$
$$r = -\frac{[\rho n'_x] - [\pi n_y]}{[\pi\pi] + [\rho\rho]} \qquad (14)$$

The brackets indicate the summation of similar quantities for all the stars. The weight of p and r are indicated by the denominators.

It only remains to apply these corrections and the corrections for refraction to the measured coördinates of an unknown object in order to obtain its true polar coördinates. This is effected by the following formulæ:

$$\Delta\alpha = X + (p + M_x)\,X + (\tfrac{1}{15}\,r \sec\delta + N_x)\,Y + [A'']$$
$$\Delta\delta = Y + (-15\,r\cos\delta + M_y)\,X + (p + N_y)\,Y + [D''] \qquad (15)$$

These coördinates applied to the right ascension and declination of c', q' give the right ascension and declination of the unknown object.

Several convenient checks may be introduced at various points in the work of obtaining the plate constants. The algebraic sums of X and Y should each differ from zero only by the accumulated errors of computation. This is also true for x, y, and for n'_x, n_y. In the equations of condition the sums of the coefficients should also be zero.

When it is desired to apply an independent check upon the last steps of the solution the values of p and r should be substituted in the equations of condition *as a whole*. The values of these quantities will usually be too small to obtain a satisfactory check by substituting in a single equation.

An excellent check on the derivation of the plate-constants and the final constants for the reduction of the unknown objects [in (15)] is furnished by deriving the right ascension and declination of one of the catalogue stars from the plate measures, along with the unknown objects, and comparing the resulting place with the catalogue place. The star selected should be one giving the largest residuals before the solution.

In large or special problems of measurement and reduction special treatment, suited to the case in hand, can usually be employed to advantage. In such problems much of the work may often be kept wholly in rectangular coördinates, with a great saving of labor.

It is not necessary or desirable to enter into a discussion of special methods in a paper of the present kind.

Many of the formulæ used in this paper are based on Jacoby's well-known four-constant method.

Example.

As an example we shall take the solution of plate No. 1702, of the sixth satellite of Jupiter. This plate was obtained with the Crossley Reflector on October 14, 1906, between $13^h\,52^m\,0^s$ and $14^h\,22^m\,0^s$ Pacific standard time.

The measurements were made on the Stackpole Measuring Engine of the Lick Observatory. The scales of this engine are divided in inches. Scale A was used in measuring X coördinates and scale B in measuring Y coördinates. The approximate values of these scales are as follows—

Scale	A	(X coördinates)	$\log \frac{1}{15} s = 1.81602$
"	B	(Y ")	$\log s = 2.99290$

The spaces on the two scales are not exactly the same but are nearly enough *uniform throughout each*, so that no corrections for division-errors need be applied.

The coördinates resulting from this plate are—

	2646	2649	2656	2663	2667	Mean	Check	VI
X_o''	−0.5398	−0.3400	+0.0536	+0.9046	+1.1503	− 62.62		+0.2040
Cor. for inclination*	+ 15	− 62	+ 1	− 36	+ 20	+ 149.17		− 3
X_o'	−0.5383	−0.3462	+0.0537	+0.9010	+1.1523	+ 86.55		+0.2037
X_o	− 38.″11	− 24.51	+ 3.80	+ 63.79	+ 81.58	+ 17.310		+ 14.422
Reduction to c.g.	− 17.310							
X	− 55.42	− 41.82	− 13.51	+ 46.48	+ 64.27		−110.75	− 2.888
$M_x X$	− .02	− .02	0	+ .02	+ .02		+110.75	− .001
$N_x Y$	0	0	0	0	0			+ .001
X'	− 55.44	− 41.84	− 13.51	+ 46.50	+ 64.29			− 2.888
Y_o'	−0.4428	+1.8530	−0.0252	+1.0744	−0.5994			+0.0900
$Y_•$	− 435.″6	+ 1823.0	− 24.8	+ 1057.0	− 589.7	− 1050.1		+ 88.54
Reduction to c.g.	− 365.98					+ 2880.0		− 277.44
Y	− 801.6	+ 1457.0	− 390.8	+ 691.0	− 955.7	+ 1829.9		+ .01
$M_y X$	+ .1	+ .1	0	− .1	− .2	+ 365.98	+2148.0	− .09
$N_y Y$	− .2	+ .5	− .1	+ .2	− .3		−2148.1	− 277.52
Y'	− 801.7	+ 1457.6	− 390.9	+ 691.1	− 956.2			

* In the Stackpole engine, the slides are not exactly at right angles to each other—the Y slide has a deviation of 11′ 35″ which we shall call I. The correction to X''_o for the above photograph is of the form $-Y \sin I$. X''_o is the coördinate *uncorrected* for I. This deviation is not large enough to affect the Y coördinate sensibly.

The refraction constants for this plate (latitude of the Lick Observatory 37° 20′ north) are found from formulæ (10) and (11) and the value 1.7049 (logarithmic) of k, to be

$$M_x = + .000420$$
$$N_x = - \quad 2$$

$$M_y = - \quad 2633$$
$$N_y = + \quad 309$$

Using X_0, Y_0 as arguments, curvature corrections are obtained from (5) (6) (7) and then c', q' from (3) and (4) and x and y from (8) as follows:

Star	2646 s	2649	2656	2663	2667	
α	6h 47m 42.72	47 56.16	48 24.60	49 24.62	49 42.20	•
−[A″]	— .03	+ 0.9	.00	— .14	+ .10	43m 10s.32
α′	6 47 42.69	47 56.25	48 24.60	49 24.48	49 42.30	6 48 38.064
center c′	6 48 38.06				check	−110.64
x	— 55.37	— 41.81	−13.46	+46.42	+64.24	+110.66
δ	+22° 15′ 52″.6	53 29.6	22 43.3	40 43.9	13 18.5	
−[D″]	+ 0.3	+ .2	.0	+ .8	+ 1.2	146′ 10″.4
δ′	+22 15 52.9	53 29.8	22 43.3	40 44.7	13 19.7	+22° 29 14 .08
center q′	22 29 14.1				check	−2146.4
y	— 801.2	+1455.7	−390.8	+ 690.6	— 954.4	+2146.3

The residuals n'_x and n_y are found from (9) to be

n_x	— s.07	— .03	— .05	+ .08	+ .05	
n'_x	—1″.0	—0.4	—0.7	+1.1	+0.7	check—0″.3
n_y	—0″5	+1.9	—0.1	+0.5	—1.8	check .0

The following equations of condition are formed according to (12). From the right ascensions

−8 p	− 8 r	−1″.0 =0	
−6	+15	−0 .4	
−2	− 4	−0 .7	
+6	+ 7	+1 .1	
+9	−10	+0 .7	
−1	0	−0″.3	check

and from the declinations

− 8 p	+8r	−0″.5	
+15	+6	+1 .9	
− 4	+2	−0 .1	
+ 7	−6	+0 .5	
−10	−9	−1 .8	
0	+1	0 .0	check

In practice it is not necessary to write out the equations of condition in full, as above. The solution may be performed directly by (14), as follows. The auxiliary quantities are first formed with Crelle's Tables.

Star	2646	2649	2656	2663	2667	[ ]
$\pi\pi$	64	36	4	36	81	221
$\rho\rho$	64	225	16	49	100	454
$\pi n'_x$	+ 8 0	+ 2.4	+ 1.4	+ 6.6	+ 6.3	+ 24.7
πn_y	+ 4.0	− 11.4	+ 0.2	+ 3.0	− 16.2	− 20.6
$\rho n'_x$	+ 8.0	− 6.0	+ 2.8	+ 7.7	− 7.0	+ 5.5
ρn_y	+ 4.0	+ 28.5	+ 0.4	+ 3.5	+ 18.0	+ 54.4

$$[\pi\pi] + [\rho\rho] = 675$$
$$[\pi n'_x] + [\rho n_y] = +79.1$$
$$[\rho n'_x] - [\pi n_y] = +26.1$$

$$\therefore \quad p = -.001172$$
$$r = -.000387$$

It is not necessary to use all the significant figures in the coefficients. In the above example two places have been rejected throughout the work and restored after p and r were obtained. No real accuracy is lost and all the computations can be made mentally and with Crelle's tables.

Substituting these values of p and r in the equations of condition after rendering the signs of the coefficients homogeneous and combining, we have the following normal equation,

$$+25\,p \;-37r\; +1.''3 = 0$$

and its substitute

$$-2''.9 + 1''.4 + 1''.3 = -0''.2$$

This representation is entirely satisfactory.

By means of (15) we now obtain the position of the satellite.

As a further check on the work we shall also derive the place of star 2667 from the photographic measures.

			Star 2667			VI Satellite
X'			+ 64ˢ.29			− 2.888
pX'			− .08			+ 3
$(\frac{1}{15}\, r \sec \delta)\, Y'$			+ .03			+ 8
$[A'']$			− .10			+ 3
$\Delta\alpha$		+ 1ᵐ	4ˢ.14			− 2.874
center	6ʰ	48	38 .064			
α 1906.0	6	49	42 .20	6ʰ	48ᵐ	35ˢ.190
Y''			−956''.2			−277''.52
$(-15\, r \cos \delta) X'$			+ .3			− .02
$p\, Y''$			+ 1.1			+ .33
$[D'']$			− 1.2			− .04
$\Delta\delta$		−15'	56.''0		− 4'	37.''25
center	+22°	29'	14.''08			
δ 1906.0	+22	13	18.1	+22°	24'	36.''83

The photographic position reproduces the catalogue right ascension of the star 2667 exactly, to two decimal places, and differs but 0″.4 in declination. This representation is extremely satisfactory and not only shows that the solution has been correctly performed with a real improvement of the plate constants but that the original catalogue place is unusually accurate. Such a close accordance will, in general, not be obtained.

It should be remarked that no check is possible on the reduction of the *unknown objects*, except a repetition of the work or an independent computation.

The above procedure is adapted to any field of 2° square or less. It may also be used for the reduction of so much of photographs taken with portrait lenses giving large fields, as lies within one degree of the optical axis.

This method is not suited to the reduction of photographs, the centers of which are within 15° of either pole.

Approximate Reduction.

After a few plates have been reduced, the scale-value is sufficiently well-known for many purposes where the greatest accuracy is not required. Not all plates will justify the refinements of a rigorous solution.

If sufficient care is taken in orienting the plate during measurement, no solution for plate constants need be made, with a consequent great saving of time.

We shall now work out the preceding example after the approximate method.

	2646	2649	2656	2663	2667	Mean	check	VI
X_o'	−0.5383	−0.3462	+0.0537	+0.9010	+1.1523			+0.2037
X_o	− $38^{s}.11$	− 24.51	+ 3.80	+ 63.79	+ 81.58			+ 14.422
Reduction to c.g.	− 17 .310							
X					+ 64.27			− 2.888
$M_x X$					+ .02			− 1
$N_x Y$					0			+ 1
X'					+ 64.29			− 2.888
$[A'']$					− .10			+ 3
$\Delta\alpha$					+ 64.19			− 2.885
Y_o'	− 0.4428	+1.8530	−0.0252	+1.0744	−0 5994			+0.0900
Y_o	− 435.″6	+ 1823.0	− 24.8	+ 1057.0	− 589.7			+ 88.54
Reduction to c.g.	− 365. 98							
Y					− 955.7			− 277.44
M_y X					− .2			+ .01
$N_y Y$					− .3			− .09
Y'					− 956.2			− 277.52
$[D'']$					− 1.2			− .04
$\Delta\delta$					− 957.4			− 277.56

c', q' are derived exactly as in the complete solution. Applying the $\Delta\alpha$ and $\Delta\delta$ just found we have,

	Star 2667			VI Satellite		
$\Delta\alpha$		+ 1^m	$4^s.19$			− $2^s.885$
center c'	6^h	48	38 .064			
α 1906.0	6	49	42 .25	6	48	35 .179
$\Delta\delta$		−15′	57″.4		− 4	37 .56
center q'	+22°	29′	14″.08			
δ 1906.0	+22	13	16 .7	+22	24	36 .52

The reduction from the photographic measures, of one star *having large coördinates*, shows at once whether our assumptions as to scale-value and orientation are sufficiently exact for the purpose, and also furnishes a check on the computation.

Comparing the position derived for the satellite with that obtained from a rigorous solution, we find that they differ only $0^s.01$ in α and 0″3 in δ. It is known that the scale value is too large by about 0.001. Had the best possible preliminary value of the scale been used even the above small residuals would have been materially reduced. The same consideration also applies to the residuals found for star 2667.

A little precaution in having the object (if only one is to be observed) near the center of the plate and near the center of the system of comparison stars, will render the approximate method practically as accurate as the rigorous one.

In these examples I have chosen to apply the refraction corrections in the first stages of the process.

A still simpler method for getting a position may be resorted to, when it is not desired to rest it upon several stars. The orientation may be determined from a trail or from two stars. The rectangular coördinates are then measured from the nearest star, or preferably from *two* stars as symmetrically situated about the object as possible. These coördinates are then converted into $\Delta\alpha$ and $\Delta\delta$ using the best scale-value available. The declination used in the $\Delta\alpha$ conversion should be midway between that of the object whose place is sought and of the star. The positions obtained from both stars are then combined.

It does not seem to be necessary to illustrate the above simple method with an example fully worked out, as the necessary steps will readily suggest themselves. If only one star is used and the $\Delta\alpha$ is large, the curvature correction should be applied to the $\Delta\delta$. The effect of curvature on the $\Delta\alpha$ is sufficiently taken into account by using, in the conversion, the declination of the point midway between catalogue star and object.

Mount Hamilton, California.

March 8, 1907.

THE PLACE OF ORIGIN OF THE MOON—THE VOLCANIC PROBLEM.

WILLIAM H. PICKERING.

In 1879 Professor George H. Darwin propounded the view that the Moon formerly formed a part of the Earth. That it was originally much nearer to the Earth than it is at present, and is now slowly receding from us, was clearly shown by his equations. After considerable discussion, his conclusions have been accepted by the great majority of astronomers, although many of the geologists do not view them with favor. Assuming the correctness of his hypothesis, it will be of interest to determine, first, if possible, from what part of the Earth the Moon originated, and, second, to follow out our conclusions on this point and see to what results they may lead.

When the separation took place, it has been shown that the combined planet was not very much larger than is the Earth at present. It must therefore have been mostly in the solid or liquid condition. If in the latter state, it is obvious that no indication of the Moon's former place could be found at the present time. Very few astronomers or geologists today, however, believe that the Earth ever was completely liquid. It has probably always been partly solid, partly liquid, and partly gaseous. It is composed of such diverse materials, and these are exposed at different points throughout its volume to such diverse pressures, that, unless we assume it to have condensed from a highly incandescent nebula, which is unlikely, we should scarcely expect it ever to have presented a uniform liquid surface.

The surface was probably hot, but how hot we have no means of knowing. Beneath the surface, however, where radiation was impossible, much higher temperatures were found, as is still the case and in what follows we shall assume that the interior was practically liquid, or was ready to become actually so where relieved of the pressure due to the gravity of the outer layers; that is, where the centrifugal force became sufficiently high, as in the equatorial regions. Precisely how the Earth came into its present form, whether by planetesimal condensation or otherwise, does not concern us here. We merely assume that in these early days the Earth was in much the same condition that we find it at present, except that it was hotter. We also assume that it was slowly condensing from a more bulky form, rendering fission possible.

These processes of fission and condensation we see going on all around us at the present time in the stellar universe, as indicated by the variable stars of short period and the spectroscopic binaries. It therefore requires no great stretch of the imagination to conceive that it may also have occurred on a smaller scale in the case of our Earth and Moon.

FIGURE 1.

It does not follow, however, that our combined planet was ever incandescent. Indeed, this seems to be unlikely. A cold nebula which is later to condense into a sun must almost necessarily be composed largely of solid matter. The electric disturbances by which we see it, illumine only the gaseous portions, but the metallic elements must be there nevertheless, all the time unseen.

Assuming then a hot, solid, ellipsoidal Earth, with an interior more or less liquid, at least beneath the Equator, revolving on its axis once in about four or five hours, we have a picture of our as yet moonless planet as conceived by the astronomer. As it continued to cool, vast volumes of steam and other gases escape from its interior, increasing its density and diminishing its volume.

As its volume diminished, its speed of rotation increased, until by centrifugal force, as explained by Darwin, the Moon was born. If the crust was solid, and if the Moon escaped from it, it is almost certain that a scar of some sort would have been left and it is of interest to see if we can find it.

The specific gravity of the Earth as a whole is 5.6. That of the surface material ranges in general between 2.2 and 3.2, with an average of 2.7. The specific gravity of the Moon is 3.4. This indicates clearly that the Moon is composed of material scraped off from the outer surface of the Earth, rather than of matter obtained from a considerable depth. At the same time, the specific gravity 3.4 indicates that the layer of material removed had an appreciable thickness.

As is well known, the land and water are very irregularly distributed over the surface of our globe. If we erect a perpendicular from a point situated one thousand miles to the northeast of New Zealand and view the Earth from a distance in this direction, we shall find that very little land will be visible, while the outline of the Pacific will approach the form of a circle.

Figure 1 is a map of the globe on zenithal projection, where the radii are proportional to the actual distances represented. There is no distortion, therefore, in the radial direction, and the exact shape of the Pacific with regard to a great circle shown. The inner circle represents the circumference of the globe, and is therefore 90° from the central point. The latitude of this point is 25° S. Away from the center the tangential distances necessarily become more and more distorted, the distortion at the circumference making them appear $\frac{\pi}{2}$, or 1.6 times too large.

Figure 2 is taken from Gilbert's *Continental Problems of Geology* (Smithsonian Report, 1892,) p. 164, and is founded on the results of the Challenger expedition as deduced by Murray. In it ordinates represent feet, and abscissas areas, the extreme abscissa representing the total area of the Earth's surface. This area is composed chiefly of two plateaus: one the continental, whose mean altitude is 1000 feet above sea-level, the other the oceanic, whose mean altitude is —14,000 feet.

It will be noticed that the edge of the continental plateau is below sea-level, but not more than 1,000 feet below it. This contour may be taken, therefore, as the true boundary more properly than the water-line itself. In Figure 1 it is indicated by a dotted line. Its position near the Antarctic continent is unknown. The location of the latter, excepting where indicated by the full line, has not been determined. The line composed of dashes therefore indicates its maximum possible area.

If we travel north 90° from the central point of Figure 1, to the immediate vicinity of Bering Strait, and erect another perpendicular, from which we again examine the globe, we shall obtain a view resembling Figure 3. In this map, which is drawn in orthographic projection, there is no tangential distortion, and the appearance is that which the Earth would have if seen from a great distance. The vertical line is a meridian; the horizontal

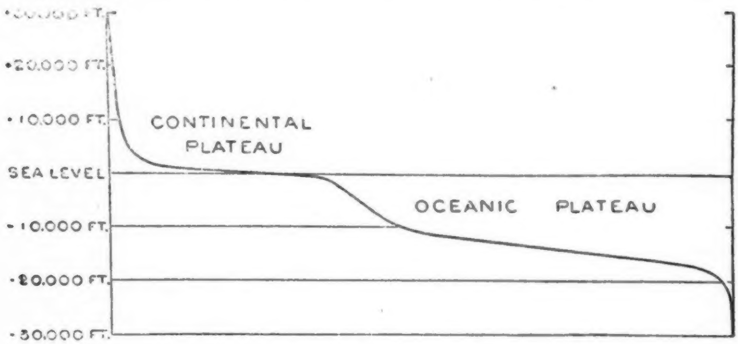


FIGURE 2.

is a projection of the inner circle shown in Figure 1. The continents and islands at the edges of the disk have been allowed to project out beyond the ocean beds in order to make more evident the systematic grouping of the continental masses on one side of the globe. With the exception of Australia, the Antartic continent, and a small part of South America, all represented in the lower half of Figure 1, there is no important land on the water side of the globe, not shown in Figure 3.

An inspection of this figure shows that the Earth's center of gravity, which is the center of the circular arcs, does not coincide with its center of volume, and this deviation would be still more marked were the mobile portions of the surface—i.e., the oceans—drawn off. The center of gravity would then be slightly raised in the figure, and the center of volume still more so. The ocean side of the solid Earth has obviously a higher specific gravity than the continental side.

It is the general opinion among geologists that the continental forms have always existed—that they are indestructible. How' then, could they have originated? We know something of the permanent surface features of three bodies in the universe besides the Earth; namely, the Moon, Mars, and Mercury. None of these. shows us anything resembling the irregular terrestrial distribution of the high-and low-level plains, of our continents and oceans.

FIGURE 3.

If we examine more minutely the coasts of our great oceans, we shall find the Pacific bounded by a nearly continuous line of active or extinct volcanoes, and this is true whether in North or South America, Asia, the East Indies, New Zealand, or Antarctica. The only possible break is the east coast of Australia, but even here there is a line of volcanic islands, lying a short distance off the coast, stretching from New Guinea more than half-way to New Zealand. The coasts of the Pacific are generally mountainous and abrupt, and composed of curves convex toward the ocean.

The Atlantic coasts, on the other hand, are generally low, flat'

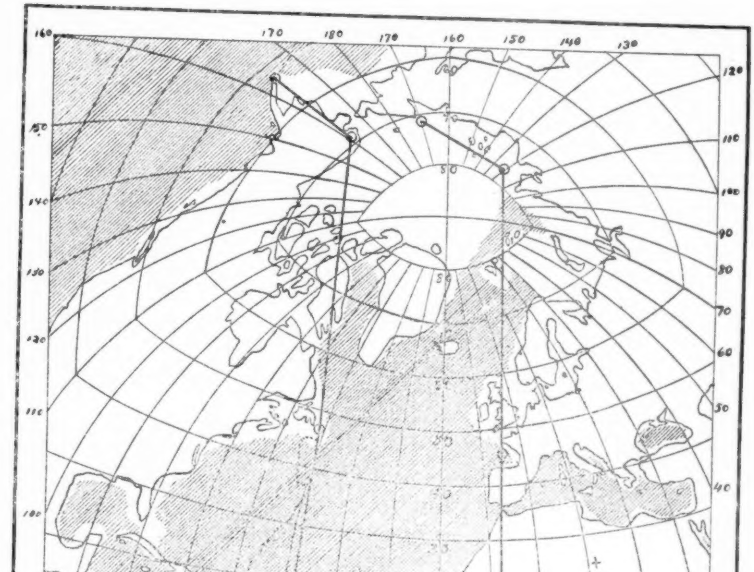


Figure 5.

and composed of curves as often concave as convex. As to volcanoes, they are few and scattering. The only conspicuous exception to the general rule is the range of the Lesser Antilles, which both in form and volcanic nature reminds us of the Pacific coast of Asia. The Indian Ocean resembles the Atlantic, except where it approaches the vicinity of the Pacific, and there the characteristic volcanoes again appear.

A curious feature of the Atlantic Ocean is that the two sides have in places a strong similarity. Figure 4 is drawn in globular projection, which is used so frequently for the hemispheres in ordinary atlases, except that in this instance the projection is carried over the pole onto the other side. This projection gives very little distortion in the vicinity of the central meridian, which is the portion of the map to which we shall especially refer. The shaded areas represent those parts of the ocean that are more than 1,000 feet in depth. Regarding the unshaded area between America and Asia we have no information.

When the Earth-Moon planet condensed from the original nebula, its denser materials collected at the lower levels, while the lighter ones were distributed with considerable uniformity over its surface. At the present day we find the lighter materials missing from one hemisphere. The mean surface density of the continents is about 2.7. Their mean density is certainly greater. We find a large mass of material now up in the sky, which it is generally believed by astronomers formerly formed part of our Earth, and the density of this material, after some compression by its own gravity, we find to be 3.4, or not far from that of the missing continents. From this we conclude that this mass of material formerly covered that part of the Earth where the continents are lacking, and which is now occupied by the Pacific Ocean. In fact there is no other place from which it could have come.

Who it was that first suggested that the Moon originated in the Pacific is unknown. The idea seems to be a very old one. The object of the present paper is to find what support for this hypothesis is afforded by the results of modern science, when examined both qualitatively and quantitatively.

The volume of the Moon is equivalent to a solid whose surface is equal to that of all our terrestrial oceans, and whose depth is thirty-six miles. It seems probable, therefore, that at this time the Earth had a solid crust averaging thirty-six miles in thickness, beneath which the temperature was so high that the materials were in places liquid, and in other places only kept solid by the enormous pressure of the superincumbent material. When the Moon separated from us, three-quarters of this crust was carried away, and it is suggested that the remainder was torn into to form the eastern and western continents. These then floated on the liquid surface like two large ice-floes.

If their specific gravity was the same as that of the Moon, 3.4, since the continental plateau averages nearly three miles higher than the ocean bed, the specific gravity of the liquid in which they floated must have been 3.7. Later, when this liquid surface cooled, the huge depression thus formed was occupied by our present oceans.

The volcanic islands in the oceans, such as Hawaii, were obviously formed after the withdrawal of the Moon, and are analogous to the small craters scattered over the lunar *maria*. While their surface material presents no extraordinary density, the lava being full of bubbles and small cavities, interesting results have been obtained by the Coast Survey with the pendulum. Observations were made by E. D. Preston near the summit, and on the slopes of Mauna Kea, Hawaii, at altitudes of 13,060, 6,660, and eight feet. He writes:

"It appears that the lower half of Mauna Kea is of a very much greater density than the upper. The former gives a value of 3.7 and the latter 2.1, the mean density of the whole mountain being 2.9. This is somewhat greater than that found for Haleakala [a neighboring volcano] and is notably larger than the density of the surface rocks. Indeed, this appears to be the highest value yet deduced from pendulum work."*

The remark of Major Dutton† is interesting in this connection, that a part of the bulk of these mountains is due to accumulation, and a part to uplifting. The upper half is clearly due to matter, chiefly scoria, which has been expelled from the various vents. The lower half is probably due to the slow uplifting of the former ocean bed.

It would seem as if borings carried on in this vicinity to a depth of only a few hundred feet would bring to the surface the same kind of rock material that, beneath the continents, would only be found at a depth of many miles. Presumably this material would turn out to be lava similar to that found on the surface, save that under the great pressure the innumerable little cavities, rendering the material generally so porous, would have practically disappeared. The fact that its density, 3.7, as determined

* *American Journal of Science*, Vol. CXLV (1893), p. 256.

† *U. S. Geological Report*, 1882-83, p. 195.

by Preston, coincides with the theoretical value just deduced is of interest.

Turning now to Figure 4, six points indicated by circles have been marked along the coast-line of the eastern continent. Corresponding to these, six similar points have been marked along the American coast. The two broken lines joining these various points are slightly inclined to one another, but the other small differences in relative position and distance are apparent and not real, being due to the necessary slight distortion of the map. The South American continent does not fit well into this arrangement, and does not appear to have remained perfectly parallel to North America during its transit across the fiery ocean, in obedience to the pull of the Moon. Instead, it seems to have rotated slightly, as shown, about a point somewhat to the east of the Isthmus of Panama.

In trying thus to match the continents together, we must take the outline of the continental plateau rather than the coast-line. Five-sixths of the area of the Atlanic basin is thus very well accounted for, but there still remains a considerable area east of the United States, together with the Gulf of Mexico, and the Caribbean and Mediterranean Seas, not explained. The eastern outline of the Atlantic area is indicated by the dotted line.

The antipodes of the central spot in the map of the Pacific is indicated by the cross in northern Africa. If the ultimate releasing force which caused the disruption of the Moon was, as has been supposed, the solar tides, we should expect that a certain amount of material might escape from both sides of the Earth. If the Sun were overhead at the central point in the Pacific, then within less than an hour, using Darwin's rate of rotation, it would have been exactly opposite to the area in question in the Atlantic, Gulf, and Caribbean Sea.

The similarity of the Lesser Antilles to the Asiatic islands, already pointed out, corroborates this explanation. It is also to be noted that the greatest depths in the Atlantic, 21,000 feet, are found along the eastern boundary of this region. Similarly, one of the deepest parts of the Pacific, 31,000 feet, is indicated by the × close to the central point on the map, Figure 1. Around this deep portion on the east, north, and west is a shallower area rom 15,000 to 20,000 feet in depth, and then, as we approach the continents, again a deeper area.

All those who have studied the stratification of the Appalachian egion have concluded that the sediments came chiefly from the east. Such extensive deposits require a larger land area than now exists; in fact, one is needed of continental proportions. Whether these deposits are sufficiently ancient to be explained by the lunar hypothesis the writer is not prepared to say.

There are several coincidences relating to the position of the central point of the Pacific which may or may not be accidental. The close coincidence with the very deep area above noted is the first of these. The second relates to its latitude, —25°. This is within a degree and a half of the tropic of Capricorn. The tropics are the lines on a uniform sphere where the direct solar tidal pull acts for the greatest length of time on any particular area of rock. Here also the leverage of the tidal pull on the Earth's crust would be greatest in displacing a protuberant equatorial ring. If the Moon were generated from the Earth by centrifugal force, liberated by the tides, we should expect the central point to coincide with one of the tropics of that time. The coincidence with the present tropic would indicate that the axis of the Earth can have changed very little in the meantime. The third and fourth coincidences are more likely to be accidental. The third is that the central point coincides in longitude with Bering Strait, where the two continents are supposed to have slipped past one another. The fourth is that the strait is almost exactly 90°, more accurately 91°, in latitude from the central point.

If the greater continents were split apart, we should by the same analogy conclude that Antarctica and Australia were drawn from the Indian Ocean; the former from the vicinity of the Cape of Good Hope, the latter farther east.

If it is true, as here suggested, that we owe our continents to the Moon, then the human race owes far more to that body than we have ever before placed to its credit. If the Moon had not been formed, or if it had carried away the whole of the terrestrial crust, our Earth would have been completely enveloped by its oceans, as is presumably the case with Venus at present, and our race could hardly have advanced much beyond the intelligence of the present deep sea fish. If the Moon had been of but half its present bulk or had been slightly larger than it is at present, our continents would have been greatly diminished in area, and our numbers decimated, or our lands over-populated.

Connected intimately with the origin of the continents is the problem as to the cause of volcanoes, and why they are at present always situated near the sea. A point that is of the utmost consequence in its bearing on this question is the fact, noted by Charles Darwin, that active volcanoes are found only where the coast-line is rising. Clearly the same cause produces both effects

A rising region, as pointed out by Dutton, must evidently be increasing its volume. This increase may occur either with or without an increase of mass. In the latter case the increase must be due to a rise of temperature. It has been shown that, if a part of the Earth's crust fifty miles in thickness were to have its temperature raised 200° F., its surface would be raised to the extent of 1,000 to 1,500 feet.* The Bolivian plateau has an elevation of two and a half miles. That of the Himalayas is about a mile higher. It is improbable that these elevations are due to this cause.

The alternative is that in the rising regions we have an increase of mass. If the mass were increased materially, it has been shown by Gilbert† that the hot subterranean region should yield to the added pressure, thus neutralizing the elevation. An added column of rock two miles in height could not possibly be supported. Apparently our last resort is to introduce some lighter material, such as water or steam. The pressure on the steam, if its temperature were above the critical point, would be so great that its density would be but little less than the equivalent extrapolated value for water. It might have one-fourth of the weight of an equal column of rock.

Liquid lava is full of water, and as the lava cools the water is expelled from it. The lava at Hilo, Hawaii, contains innumerable bubbles, indicating the presence of steam, which had been retained by it within its structure for many days, ever since it had left the crater of Mauna Loa, fifty miles distant.

Since volcanoes are intermittent in action, the charging process must still be going on at the present time; otherwise there would have been one long discharge in the distant past, which would have rendered all our present volcanoes extinct.

Since volcanoes are active only near the oceans, it has been suggested that the eruption is due to sea water that has entered by cracks in the Earth's crust and is subsequently discharged from the volcano. Volcanoes do discharge salt water, but the solid ingredients of the water do not occur in the same proportions that they do in the sea. Some of the sea salts are often found to be absent, while other salts are often found that do not occur at all in sea water. This fact together with the inherent improbability that sea water should be sucked in at a low level and pumped out at a high one, renders this explanation improbable.

* Judd *Volcanoes*, p. 347.

† *Continental Problems of Geology*, Smithsonian Report, 1892 p. 165.

Another explanation of the universal presence of water in volcanic products is that it is derived from rain water, which has percolated down through the soil. This theory, however, does not account for the fact that volcanoes are always found near the sea. Neither of these theories account for the gradual elevation of the land in volcanic regions.

Since the process of charging volcanoes with steam is still going on, and since it appears that the necessary water is not derived from either the sea or the atmosphere, the only alternative seems to be that it comes from the heavy stony material forming the ocean beds, and does not come in appreciable quantities, at present, from the lighter material forming the continents. It is evident, however, that this lighter material is sometimes cracked, permitting the discharge to take place through it. This was the case with the extinct volcanoes in central Europe, and those near the Yellowstone Park and Arizona in this country. The volcanoes at present active in North and South America seem to rise from what was probably formerly the edge of the continental plateau.

The next question that arises is: From what depth does the lava come? Judged by its temperature at the vent, unless it becomes heated by friction, by compression, or by radio-activity, on its way to the surface, which seems improbable, it must have come from a considerable distance. The rate of increase of temperature with the depth varies in different parts of the world from 20 to 100 feet per degree Fahrenheit. It may fairly be taken near the surface at 100° per mile of depth. From its surface temperature, Bonney estimates* that "lava is generally supplied from a zone situated at a depth of from 20 to 25, or possibly to 30 miles, in the crust of the Earth." The total thickness of the crust has been estimated by Fisher† at 30 miles. These values agree very well with that just computed from the volume of the Moon.

Daubrée has shown‡ that water separated from a chamber filled with steam at a temperature of about 160° C. by a close, fine-grained sandstone, passed through the slab with ease, against the outward pressure of the steam. He also found that the facility with which the water found a passage was increased by heat. There is therefore no difficulty in understanding the transmission of water through hot rocks at considerable depths. Its

* *Volcanoes*, p. 284.

† Milne *Seismology*, p. 120.

‡ *Geological Experiments*, Vol. 1, p. 238

presence, moreover, would tend to lower the melting-point of the rock, and make it more viscous.

A certain amount of water may even be transmitted in this manner down through the ocean floors; but when we consider that the transmitting medium consists of cold rock several miles in thickness, the water advancing against a constantly increasing pressure, it does not seem that the amount transmitted per year in this manner can be very large.

In our hypothesis explaining the origin of the continents, it was stated that they were composed of the crust which was either originally solid or else had already cooled sufficiently to become so. They had therefore expelled a large part of any water which they may originally have contained. The ocean beds at the time of the great catastrophe were liquid. They therefore absorbed all the water available, if indeed they were not already saturated with it. They had a much higher temperature, having come from a greater depth, and contained much more water at this period, than the continents, and, it is believed, have been giving it out as they cooled ever since.

Doubtless the hot bases of the continents have absorbed some water from the ocean beds as the latter cooled, and the expansion and diminished specific gravity thus caused would tend to elevate them in the vicinity of the oceans. This has occurred notably in the vicinity of the Pacific, the whole of whose coasts are at the present time in a state of elevation. We can understand also that the systematic difference in material and density, extending over large areas, would render the boundaries of the continents more subject to cracks, with their resulting volcanoes and earthquakes, than other portions of the Earth's surface. A zone of territory subject to earthquakes extends around the Pacific.

As is known from its rigidity, the interior of the Earth as a whole is solid. There cannot even be at present a continuous liquid surface between the center and the crust. Beneath every active volcano, however, there must be an area from which its lava is derived. In some way, without doubt by the contraction of the Earth, this lava is caused to approach the surface, and on the way it gradually changes from a viscous solid to a viscous liquid. There are only two ways in which this change can take place: one is by an increase in temperature, the other by a decrease in pressure. The latter is probably the actual one.

Tangentially considered, the lower portions of what we may for convenience call the Earth's crust are in a state of compression, the upper portions in a state of tension. Radially all are in a state of compression. Between the upper and lower portions is a neutral surface of no tangential strain. When a crack caused by the tangential tension reaches this neutral surface, the viscous rock oozes up through it, becoming more and more liquid as it approaches the surface and the pressure is diminished. As it melts and is relieved of pressure, its density diminishes, and, if it finally reaches the surface, the erupted lava will continue to flow till the pressure at its source is reduced to equality with the hydrostatic pressure at the base of the crack. The larger the opening and the shorter the distance from the surface, the sooner will this equality of pressure occur, and the shorter be the duration of the eruption. The expansion of the bubbles of steam near the top of the crack diminishes the hydrostatic pressure, and their escape obviously causes the explosions usually noticed. The violent manifestations are therefore all generated near the surface, as is the case of a geyser.

The uprush and escape of all this material broaden the crack into a tube several hundred feet in diameter. After the lava has ceased to flow, the steam working its way up to the vent still keeps a somewhat narrowed passage open. It thus continues as a line of weakness; and when the flow of steam and viscous rock from below on all sides toward the area of diminished pressure again increases this pressure beyond the breaking strength of the resisting material, the eruption will be renewed.

Volcanoes frequently lie along arcs of circles, which if complete, would resemble the lunar *maria* both in size and shape. One of the most complete of these series of arcs has the China Sea for its center, while the volcanoes are found in the Philippines, Celebes, Java, Sumatra, the Malay peninsula, and southern China to the west of Canton. The diameter of this circle is 2,000 miles. The Japan and Bering seas are similarly partly surrounded by incomplete arcs. The shape of the latter is decidedly elliptical.

THE ART OF COMPUTING.

ROBERDEAU BUCHANAN.

For Popular Astronomy.

1. *Introduction.* Comparatively little has been written upon this subject; the writer can remember but one general article, though there are doubtless others,—that by Professor Watson, at the end of his Theoretical Astronomy. This article though brief, is good so far as it goes; but the practical computer needs fuller information about the minute details of his work.

The author having been engaged chiefly in astronomical calculations, asks the pardon of the general reader for making his references to that science, though his remarks doubtless apply to any other calculations.

Computing is an Art by itself, and the computer need not inquire whether ϕ represents a celestial arc or terrestrial longitude, to him it is merely a symbol to be used in accordance with his formula. Skill in computing, that is, the actual work of the computer, is entirely independent of a knowledge of astronomy, mechanics, geodesy, or whatever else it may be applied to; and more or less independent of pure mathematics except an understanding of trigonometrical equations. Being an Art by itself, a knowledge of astronomy is not necessary if the work is in geodesy, nor a knowledge of geodesy if the work applies to mechanics; neither do College degrees make a computer,—they only evince a preparation for this work.

A knowledge of astronomy, mechanics, geodesy, etc., or perhaps his preceptor, will tell a computer *What to do,* while his knowledge of computing tells him *How to do it.* And yet a knowledge of these sciences although it does not *make* the computer, will be of much service to him and render his work less arduous.

Professor Newcomb in his *Reminiscences,* (pp. 223-4) mentions a computer to whom the above remarks apply with much force though it must be admitted that he was rather an exceptional case.

"He was the most perfect example of a mathematical machine, that I ever had at command. Of original power,—the faculty of developing new methods, and discovering new problems, he had not a particle. Happily for his peace of mind, he was totally devoid of worldly ambition. I had only to prepare the fundamental data for him, explain what was wanted, write down the matters he was to start with, and he ground out day after day, the most complicated algebraic and trigonometrical computations with unerring diligence and almost unerring accuracy."

2. *Arrangement of the work.* The first thing to decide upon is the arrangement of the work, whether the computation is to be carried on in columns down the page or in lines across the page; and this depends greatly upon the character of the work,—whether the computation is to be made with four or five, or with seven or eight-place logarithms; it depends also upon the number of quantities to be computed; for example, suppose an ephemeris of a planet for one year which must be computed for every day

using seven-place logarithms; expert computers would arrange this work across the page placing the dates on the margin, with the precept from the formulæ at the head of each column. Occultations of fixed stars by the Moon for example may be computed with four-place logarithms, and the work being comparatively short, is more conveniently carried on in columns with the precept from the formulæ in the margin serving for all of the columns on that page. In a computation with seven-place logarithms a portion of the work may have to be computed with four or five-place logarithms; but the work is then more conveniently carried on across the page.

As to the merits of the two arrangements; that in columns is said to render the additions more easy, while that across the page greatly facilitates differencing and the detection of mistakes. The latter consideration is the more important of the two and should have its weight. The author also considers the addition to be more difficult in columns, because the logarithms may not lie on adjacent lines and must either be added two and two, or else repeated below, thus increasing the time and labor of the work.

When the work is carried on across the page, the sheets—sometimes three or four of them, can be folded lengthwise, bringing all the columns by the side of one another. If the computer will rule off in pencil the four right-hand figures of each column it will aid him in "keeping his place," while adding. When there are two columns, many good computers recommend adding or subtracting from left to right, it can generally be easily acquired, but the writer usually takes two figures at a time from right to left—either in adding or subtracting and writing the result down. Then add the next two figures, and so on.

The work carried on across the page requires less figures to be written; those that change slowly, namely, the degrees of arc or hours of time, and the first three or sometimes two figures of a logarithm need be written only when they change; whereas in the other method all these figures must be repeated in each column.

As to signs, in computing on lines the sign of the quantities need be written only against the first and last number of each page, and when they change; in the other method they may have to be written in every column.

The writer much prefers the use of the signs + and — rather than the use of the letter *n* written after negative quantities.

In computing on lines the last line of each page should be copied as the first line of the next page. This is almost indispensable when differencing.

Computing in columns should generally be preferred, when the quantities cannot be differenced, and when they are few; as for example; the determination of an orbit, the prediction of eclipses and occultations for a given place, etc. To guard against mistakes, the only way here is to revise the work or make use of check formulae; but these do not always serve to re-compute the work of which the following may be given as an example:

$$\frac{\sin b \sin c \sin (C - B)}{\sin a \cos A} = \pm \tan i$$

These quantities are the constants for the equator, and are supposed to have been computed for future use, and when combined according to this formula, the two members should agree exactly. If they do not, a mistake somewhere is indicated.

The author has found this check very useful. In equations like the following:

$$m \sin M = a$$
$$m \cos M = b$$

m when computed by both sine and cosine, should agree within *one* unit of the last figure, whether four, five or seven-place logarithms are used. The reason of this limitation is, that in tables of logarithms sin ÷ cos *may* differ one unit from tan.

3. *Addition and Subtraction Logarithms.* These are employed for the addition or subtraction of two numbers given by their logarithms, without passing to numbers. The principle is explained by Professor Chauvenet in his Trigonometry, page 211; and a method is given by Professor Watson in his Theoretical Astronomy, page 115-6, for using a table of logarithmic sines for the same purpose. Zech's Tables are the principal, or perhaps the only ones for seven-place logarithms. No general rule can be given when to use them and when to use natural numbers; suggestions only can be given to guide the computer in his choice. In such an equation for example as the following,—

$$\cos. a = \cos. b \cos. c + \sin b \sin c \cos. A$$

if the two terms are known to be correctly found, addition and subtraction logarithms will be the more accurate, besides saving time and labor; but as small mistakes in the numbers cannot always be found by differencing the logarithms, a mistake may be carried on to the left member, and appear later when passing to numbers. If natural numbers are used for the two terms, there is an unavoidable error in each term not exceeding ½ a unit of the last decimal, so that on this account the work may not be quite so accurate as that by the preceding method; moreover it requires more time and labor. Another point which may guide the computer in his choice, is whether *a* in the left member is required in natural numbers, or by its logarithm. Generally if the successive quantities in a column vary much, natural numbers should be used. Experience is the best guide here; and other things being equal that method which is easiest and requires least time is the most accurate.

4. *Differencing for Errors.* It is important that the computer should check his work from time to time, as he proceeds and the intervals selected for a long computation should be such that the work may be easily differenced and accurately interpolated, if necessary. On this subject the computer may consult Loomis' Practical Astronomy (an excellent article for a beginner); also Professors Chauvenet and Watson in their Astronomies.

The computation being carried on across the page, the quantity to be differenced will be in a column. Subtract algebraically the first one from the second placing the difference, with its proper sign, adjacent and below the line; subtract the second from the third, the third from the fourth, etc. The column so formed is the column of First Differences Δ_1, which is the proper designation since the numbers are Finite Differences. Proceed in the same manner forming the Second Differences Δ_2, placing this *on* the line; and so proceed until the differences become small. Generally three columns will be sufficient and rarely not over five.

If there is a mistake which we may call (a-b) in the original column it will affect Δ_1, above and below the line by + (a-b),—(a-b); and in the other columns will be increased and multiplied thus $\Delta_2 +1_1-2_1+1$; $\Delta_3+1_1-3_1+3_1-1$; etc., which are the binomial coefficients of the quantity $(a\text{-}b)^n$ where n represents the order of the difference. The line in which the mistake occurs is thus pointed out, being that in which the differences are the greatest.

If a number is less than the modulus 0.4342945, its differences will be less than those of its logarithm, and the reverse of it is greater than the modulus. A column of logarithms, whose numbers pass through 0, will run up to ∞ negative and the differences will do the same. Here, the 7th, 6th, 5th, 4th figures may successively be omitted in the differences for several lines. After passing through ∞ the signs of the even differences will change, but those of the odd differences will remain the same. This is a difficult place to find mistakes, as more than one is liable to occur. A mistake will usually be found nearer to the ∞ point than the differences indicate. All mistakes, even small ones should be corrected until the differences run smoothly.

When a column differences well, the computer will have a satisfaction in going on with the rest of his work; but one who passes over small mistakes will soon find his whole work covered with them, and each one makes it more difficult to find succeeding ones, for the differences will not always run regularly enough to indicate the line containing a mistake.

In the theory of Finite Difference the symbol Δ is distributive, as indicated by the expression

$$\Delta(a \pm b) = \Delta a \pm \Delta b.$$

That is if a and b represent two columns that have been differenced, the sum of the differences line by line will be equal to the differences of the sum of of two columns $(a+b)$. In the example annexed the differences (of any order) of columns a and b are seen to equal those of the column (a+b).

EXAMPLE.

Arg.	a	Δ_1	Δ_2	Δ_3	b	Δ_1	$(a+b)$	Δ_1	Δ_2	Δ_3
1	+ 1+	7			+ 1	+4	+ 2	+ 11		
2	8	19	+12	+6	5	4	13	23	+12	+6
3	27	37	18	6	9	4	36	41	18	6
4	64	61	24	6	13	4	77	65	24	6
5	125	91	30	6	17	4	142	95	30	6
6	216	127	36	6	21	4	237	131	36	6
7		169	42	6		4		173	42	6
8		217	48	+6		4		221	48	+6
9		+271	+54			+4		+275	+54	
10	+1000				+37		+1037			

We can verify the subtraction of a column of differences by adding them together between any two dates. We can also extend a column beyond the last computed date by beginning with the highest order of differences, suppose for example 6 of group 1, then getting Δ_2, 36; Δ_1, 127, with which we get the value of a next succeeding 216. If the differences of a function end in zero, the result will be exact; but otherwise, only approximate.

If we have a column of numbers, b to be added to a, which is not computed for every value of a, we may interpolate b, but need not carry out the function, as in the example, Arguments 6 to 10. Then add the computed dates 21 and 37 to a and also all the differences line by line, giving in the group for (a+b) 237 and 1037, and by the differences we can fill in the intermediate values. In this way we are actually adding together two numbers, one or both of which may be unknown; (though we may be able to find them.) The computer may find ways of using these suggestions, and shorten the time and labor of his work by using small quantities instead of large.

5. *On the use of eight-place logarithms.* Schron's seven-place Tables contain marks on certain figures of the 7th decimals to indicate that they should be taken 0.25 less than the printed figure; while all the others of the 7th decimal should be taken 0.25 greater. The writer does not consider that there is a particle of gain in accuracy by this expedient; because, firstly, the logarithms are not then eight-place, but only an approximation, and secondly, the computer has now four figures to carry in his mind for the proportional parts instead of three, so that small mistakes are more liable to occur. To be consistent he should change the tabular proportional part by ±0.25 or ±0.50 of a unit of the last figure. It is doubtful whether this method of Shron's can affect the second decimal of arc more than 0.″02 or 0.″03, and this second decimal being thrown off at the end of the work; What gain is there?

The writer suggests that instead of using Shron's system for eight-place logarithms, seven-place be used, but that all *natural numbers* be carried out to eight-place. In this way the whole value of the logarithm is retained, as it is in using addition and subtraction logarithms.

6. *Hints on using logarithmic tables.* The computer will do well to accustom himself to carry the tabular logarithm of seven figures in his mind at one time, to write three on the computing sheet, and four right-hand figures on a slip of paper underneath, on which he can get the proportional part. This latter can be gotten by Crellé's Rechentafeln and the sum carried over to the computing sheets. The work is almost as rapidly done without using Crellé, by taking out the proportional part for the first figure of the argument, setting it down under the four figures on the slip of paper, then getting the proportional part for the two other figures of the argument and finding the sum on the slip of paper. The use of a slip of paper avoids many small mistakes. It may be dispensed with as the beginner progresses. When the argument consists of only two significant figures, the whole proportional part can be taken out mentally, for example, 3.06, 0.22, 2.70 etc., and computing backwards, 3.96 = 4.00 — 04, 9.21 = — 0.79 etc.

A great saving in time is made, when it can be done, by writing the whole tabular logarithm on the computing sheets and placing the proportional part in a column following. In searching for a mistake, this is especially convenient. But when the logarithm is decreasing, we must revert to an expedient, for example for the sine of 130° 27′ 43″.72 compute backwards setting down the tabular sign of 130° 27′ 50″ and the proportional part for 6″.28.

It is a saving of time in the future to write the degrees from 45 to 360 in the tables. The printed figures do not belong where they are usually placed but on the corners of the tables as in the subjoined figure which shows where the place of the number changes:

0	135
90	45

A beginner should regard signs carefully, (the sign of a term depending upon the signs of its factors,) and write the signs + or — before each column, as suggested above. Do not repeat figures that change slowly that is, the degrees usually, and the first two or three figures of a logarithm. Constant quantities may be written on a slip of paper and placed below the numbers they are to be added to. For small angles Bruhn's Logarithms are indispensable for they give the first six degrees to every second. The sines of small angles can be conveniently found by the formula

$$\sin \beta = S\,\beta.''$$

where β'' is the angle in seconds and decimal, and S is given in the Table.

Manuscript Tables are frequently resorted to and graphic methods may be devised for small quantities or approximate results. Special methods, sometimes quite complicated, have been devised as occasion requires. Of these may be mentioned a graphic method of solving Kepler's equation by F. R. Moulton in *Popular Astronomy* III, 136. Downes' Table for the approximate time of conjunction during an occultation, published in the Nautical Almanacs 1882-99. Dr. Herman S. Davis, a method of interpolating a series of numbers whose logarithms are given for equidistant arguments, Astronomical Journal, XXI, No. 498, p. 143. Convenient methods for both the Orthographic and Stereographic projections of the sphere were devised by the author of these pages for his own use and published subsequently. Sometimes a table in print is more conveniently used in manuscript. No suggestions can be given under this head as it depends upon the ingenuity and ability of the computer.

As to the number of logarithms to use in any work, seven-place will give seven figures very accurately at the beginning of the table, but not quite so at the end; the full value of the logarithm may however be retained by carrying out the resulting number to eight places. In arcs the second decimal corresponds in accuracy to the seventh place of numbers.

Anti-logarithms may be used with advantage; but the only seven-place tables are those of Shortrede, now long since out of print. In using four-place logarithms it is more accurate and quicker to take the circular functions from the five-place tables, for it avoids the interpolations. The best five-place tables are those of Professor Newcomb and F. G. Gauss, both given to minutes and containing also the addition and subtraction tables; the proportional parts of the former work give decimals of a minute and those of the latter give seconds.

The writer has long been of the opinion that a knowledge of Spherical Projections and the method of revolving the sphere should be attained by every one studying astronomy and computing; it opens the mind and renders future studies easier. A good article on this subject by Professor Wm. F. Rigge S. J., is given in *Popular Astronomy* XIV, 402.

7. *Qualifications of a Computer.* A *good* preceptor is a great advantage to a beginner; for he is then shown good methods, and kept from bad ones; and moreover he may also receive hints as to various expedients that train his mind to devise others himself. A computer thus needs *ingenuity*. He should be *steady* at his work and not let his attention be diverted by what goes on around him. *Accuracy* and *rapidity* will come naturally as he becomes familiar with his work. No one however can attain perfection. He should have *patience* especially in the beginning, for he will be slow at first. Finally, for the multiplication of small quantities, it is better to use natural numbers, when possible, rather than logarithms. The writer, having a number of multiplications to perform, some years ago, where it was not convenient to use logarithms, devised the following method, which may be useful to the reader and also serve as an example of the more simple expedients alluded to in the previous section.

8. *Multiplication of 4 × 4 figures.* Required the prroduct of 8432 by 6127. In astronomical work one of these numbers is usually a decimal, so we require only four figures in the product which we point off by a comma. Algebraically we have

$$(A + a) \quad (B + b) = AB + Ab + Ba + ab$$

Place $\begin{cases} (A + a) = 8430 + 2 \\ (B + B) = .6120 + 7 \end{cases}$

			More accurately
$A \times B$ by Crellé	$843 \times 612 = 5159\ 2$		5159,16
$A \times b$	$8 \times 7 =$ 5,6	84×7	5,88
$B \times a$	$6 \times 2 =$ 1,2	61×2	1,22
	5166,0		5166,26
Product required	.5166		.5166

In the first example one figure of A and B is multiplied in order to show where to place the product. In the second, for greater accuracy, two figures of A and B are employed; and the only error is the omission of the term $ab = .014$. The decimal point can now be inserted in its proper place before the figure 5 giving the product required.

THE BRIGHT RAYS OF THE MOON.*

H. G TOMKINS.

Part II.

(*Abstract*)

Since writing my former paper on the Lunar Bright Rays, which was published in the "Journal" of the Association, Vol. XVI., No. 9, more information has been obtained regarding the behavior of the salts in Upper India. I have also collected a considerable amount of literature on the subject. The object of the present communication is to reply to the criticisms made on my original suggestions, and also to briefly lay before the Association the further information now available.

May I point out that my note published on page 24 of the "Journal" of the Association, Vol. XVII., was appended to my paper, and is not therefore a reply to the criticisms made by Professor Pickering on it, as reported on page 12 of the same "Journal." Professor Pickering's replies to my note appear in his paper on page 27.

Disposing of Mr. Horner's remarks on the paper first, the difficulty he finds in conceiving the markings on the Moon to be salt lies, I think, in his probably never having seen the salt on the the Earth. If Mr. Horner will observe a light fall of snow, and will try to imagine the snow only on the ground and not on the trees and bushes, he will have a fair idea of the appearance of a salt tract.

---

* *Journal of the British Association*, March 20, 1907.

As regards the quantity of salt that would be required to form the bright rays of the Moon, very few people appear to realize the vast quantities that exist on the Earth, nor in picturing to themselves what the appearance of the Earth probably is from the Moon would they give these salt beds a sufficiently important place.

Before proceeding further it is necessary to state that in the literature on the subject which I have been able to get hold of, the salt is known by many names. In India the stuff is called Reh, Shor, Kallar, and Usar. In America it is known as Alkali, and the parts of the country where the salts appear are called alkali beds or tracts. It is desirable to observe uniformity in the matter of names, and in the rest of this note and future communications I shall use the term "Alkali" for the salts, and "Alkali Beds" or "Tracts" for the places where it is found.

I must apologize for not having replied earlier to the criticisms made by Mr. Saunder, and published in the "Journal," Vol. XVI., No. 9, but they are so practical and suggestive that I have taken time to think over them in order to decide what modifications of the theory, if any, would be necessary to satisfy them and what results the alterations would have on the idea as originally put forward.

The main points noticed by Mr. Saunder are:—

(1) Too much water is supposed on the Moon;

(2) Doubt whether the disappearance of the rays at sunrise and sunset can be due to conditions of illumination:

(3) Present evaporation on the Moon.

and, in "Journal," Vol. XVII., No. 1,

(4) Whether they can be of superficial nature.

The question whether, at any time in its existence, the Moon has possessed water on its surface appears to be one about which there are a good many opinions. Some selenographers have undoubtedly held that evidence of the action of water on the Moon exists, and I think I am right in believing the present Director of the Lunar Section to be one. In Neison's "Moon" the same view is held. Professor Pickering on page 34 of his work on the Moon is doubtful, and considers the evidence of water having existed on that body to be very much less marked than on the Earth. Nevertheless, Professor Pickering presupposes water on the Moon in his hoar-frost theory described in a paper recently published in the "Journal." He says, "water cannot exist in the liquid state on the surface of the Moon, because at the low atmospheric pressure found there it would instantly evaporate-

It may, however, exist just below the surface held by capillary attraction." Professor Pickering therefore admits a subsoil water and also evaporation. During the last few months I have collected much information regarding the alkali-beds, and it is interesting to find that these are two of the conditions required to bring the alkali to the surface on the Earth.

The two conditions above referred to also seem to be exactly those which Mr. Saunder in his criticism of my former paper shows as probably existing, or having at one time existed, on the Moon. Putting altogether aside for the present the question of *free* air and water having *at any time* existed on the surface of the Moon, it is conceded that water has probably been absorbed in the substance of the Moon and that evaporation has most likely taken place. The third criticism by Mr. Saunder on my paper also shows that evaporation would be assisted in the way he states by a rare atmosphere. I am much obliged to him for pointing out the mistake made by me, which was a stupid one.

Put briefly, the information now at hand shows that in the case of the Earth, the appearance of the alkali on the surface is due to evaporation. Water exists in the subsoil, and this holds the alkali in solution. Evaporation sets up currents to the surface which bring the alkali up with them. Similar subsoil water on the Moon is, I think, what Mr. Saunder refers to in his remarks; and, owing to the absence of rain, there would practically be only currents upwards on the Moon and not downwards. The result of this would be the permanent accumulation of the alkali on the lunar surface.

If water had ever been free on the surface of the Moon, then the currents would at that time have been both upwards and downwards; but, as the Moon gradually lost its water, the downward currents would cease and leave only the upward currents. These would bring the alkali to the surface and there would be nothing to carry it downwards again. It would therefore, remain on the surface. The above I think, also answers Mr. Saunder's remark in the "Journal," Vol. XVII., No. 1, regarding the reasons for supposing the cause of the rays to be deep-seated.

It will be gathered from what I have said that, although I consider the rays to be surface *markings*, it does not follow that they are wholly surface *phenomena*. The theory put forward by Nasmyth and Carpenter is mentioned. This supposed the cracking of a globe and the forcing up of some matter from the interior of the Moon into those cracks. The alkali fulfils the same conditions, the only difference being that it is brought up by evaporation from below, and does not require the cracks. It uses the much more probable channels supplied by nature—namely the pores of the Moon's soil, and it appears on the surface independently of the configuration of the land. This brings me to an important addition to the information available at the time I wrote my original paper. I there showed that the alkali appeared on *patris* and elevated ground; and Professor Pickering asks whether the same thing occurs on a large scale. I am making many inquiries regarding this, and I have heard recently of two cases in which alkali beds are said to exist in mountain ranges. I have not yet been able to verify the statement, but I have come across a tract of alkali in the Punjab, which appears to be situated along a watershed between two rivers. In most of the tracts in India which I have seen the alkali certainly tends to appear on low ridges and slightly elevated ground; but in the papers I have recently received on the subject, one officer states that the crust occurs both in depressions and on ridges, and that the capricious way in which it appears in some places and not in others is very difficult to understand. I saw a tract of this kind lately, the salt lying in depressions and not on the ridges. It is not safe to form a conclusion of any kind at present. The matter is one regarding which I hope to obtain more information during this winter, and I must leave further discussion of it for the time. Connected with the positions in which the alkali appears is the configuration of the whole system, and it is interesting to find in the two maps which I have obtained a tendency towards the shape of the lunar ray systems. The length of one of the strips of alkali extending from the salt range seems from the map to be about 700 miles and the breadth from twenty to sixty miles. Here again more information is wanted to make the matter conclusive, as one of the maps is old and incomplete.

I now come to the phenomena of the delay in the appearance of the lunar rays at sunrise and their disappearance just before sunset, which in some respects is the most important of the points noticed by Mr. Saunder. It must not, of course, be confused with the diminution in the size of certain light spots observed by Professor Pickering.

The problem which has to be solved resolves itself into the question whether the phenomena are due to physical changes of the matter of which the rays are composed or whether they are due merely to conditions of illumination. As was stated in my former paper, my opinion is that the latter will account for the peculiarities.

The present paper has been delayed owing to my desire to explain the case completely or else to suggest some modification of the theory. The problem is not an easy one. There are still several details which can be better shown by the results of actual experiments than by mere argument. I prefer therefore, to submit this paper at once, leaving the phenomena in question to a future paper, and I will merely say here that my suggestion did not refer to so-called regularly reflected light but to scattered light by which the rays are visible. It is with great diffidence, in view of Professor W. H. Pickering's remarks, that I suggest that the angle of incidence equals the angle of reflection, in the case of scattered light as well as of light reflected from a highly polished surface. The difference in direction is merely due to the condition of the reflecting surface and to the minute inequalities which exist in the case of an unpolished surface. The proportions of the scattered and regularly reflected light depend also on the same thing. If this brief explanation be applied to my former suggestions, I hope it will make them clearer. What I wish to show is that, when the Sun is low, there is not sufficient scattered light coming from the rays in the direction of the Earth to render visible the difference between them and the rest of the lunar surface. As the Sun rises, however, the scattered light is more intense, and the rays can then be distinguished. The light is reflected from the alkali in all directions, but not, I think, in quite the sense implied in the suggestion of Mr. Saunder regarding the crystals. His remarks appear to contemplate the existence of alkali in the shape of crystals with facets of commensurable area. This is not quite the case. The alkali is in the form of a powder, and must therefore be regarded as a surface. Nevertheless the light from this unpolished surface is *scattered* in the ordinary way, and it is by this light that we see the rays. The effect, therefore, in the case of Saussure would be to render the ray which crosses the formation visible at all parts of its course; but the part on the bottom of the formation, when the Sun is more or less vertical over it, might possibly appear brighter than that on the sides, and one part of the ray might become visible to observers on the Earth very slightly before another. The direction of the ray in Saussure does not, therefore, vitally affect my suggestion, but it will be of considerable interest to determine whether there is any difference in the time of appearance of its different parts. To me the phenomena seem to be due to *difference* of illumination, and I hope to show this more clearly later on. In the meantime, however, I would suggest that the peculiarity is not confined to the rays but to a large extent, at any rate, applies as well in the case of other bright spots and features on the Moon. This has only recently occurred to me in connection with the present paper, but I do not remember having ever noticed craterlets, etc., brilliant under a high Sun and equally brilliant under a low one. I have carefully examined Professor Pickering's Photographic Atlas, which is admirably adapted for illustrating anything of the kind, and it appears to bear out my suggestion. The attention of an observer seems to be drawn to the phenomena in the case of the rays and not the craterlets, etc., because sites of the latter are usually marked by elevations or some such physical features, and the eye merely follows the increase in brightness of these features that have been already marked. In the case of the rays there are no such features, and when they brighten they *seem* to appear from nothing, and similarly, when the light fades, they *seem* to disappear. This does not occur in the case of the craterlets, because, although the light fades, the elevations and peaks remain. If there were no elevations or other distinctive physical features, these formations would become invisible in the same way as the rays.

With reference to Mr. Crommelin's remarks, I do not, of course insist on the salts on the Moon being precisely the same as those on the Earth, but they must be the highly soluble salts in the Moon's composition; and sodium, as is well known, is one most commonly found in all heavenly bodies. The probability, therefore, that the salts are the same, or nearly, so, is great.

There remains the peculiarity, noticed by Professor Pickering, of the white spots round Linné, Messier, and elsewhere. The variations of the areas of these patches during the lunation appears to be due to a physical cause, and the phenomenon, it will be noticed, is diametrically opposite in character to the general tendency of rays and white patches to increase in brilliance as the Sun gets higher above the horizon. It seems necessary to ascertain whether anything of the kind occurs in the case of other patches and rays; for instance, whether although a ray gets brighter, it nevertheless decreases in width as the Sun rises on it. It will then be possible to decide whether the change is a general one, common to all rays and patches, or whether it is peculiar to a few particular formations, such as Linné and Messier. I shall probably have more to say regarding this later on.

Lahore, India,
January 9, 1907.

NOTE ON THE DETERMINATION OF THE WIRE-INTERVALS FOR A TRANSIT INSTRUMENT.*

W. H. M. CHRISTIE.

In the ordinary use of a transit instrument, the transits of stars are observed over the whole system of wires (say nine or more), and the instrumental errors (collimation in particular) are referred to the central wire, so that the wire-intervals are required mainly to refer the mean of the wires to the central wire with a high degree of accuracy.

A ready method of doing this independently of star transits is to compare the direct and reflected images of each pair of wires (reckoned from the center), the small asymmetry of each pair, relatively to the central wire, being measured by the micrometer.

Thus, with a system of nine wires, the observations would be arranged as follows:—

Wire.	Wire.	Wire.	Wire.
1D 9R	5D 5R	5D 5R	9D 1R
2D 8R	5D 5R	5D 5R	8D 2R
3D 7R	5D 5R	5D 5R	7D 3R
4D 6R	5D 5R	5D 5R	6D 4R

—the reflected image in each case being brought into coincidence (or contact on alternate sides) with the direct image.

Thus the interval between the central wire and the mean of the other eight wires is determined with the full weight of eight observations; and as the distances between the direct and reflected images of the pairs of wires are very small, the result is practically independent of errors of the micrometer screw. A moderate number of determinations made in this way should suffice to reduce complete transits to the central wire.

For incomplete transits of quick-moving stars, the interval of each wire from the center wire is required with an accuracy which should be several times greater than that of a single observation, any error in the adopted wire-interval being in this case accidental, and not systematic. A few transits of close circumpolars, or a very moderate number of transits of quick-moving stars, would amply suffice for this.

For close circumpolar stars observed on wires other than the center wire, it would, of course be necessary to determine the wire-interval from the center wire with an accuracy considerably

* *Monthly Notices*, January 1907.

exceeding that of the observation; and for such cases, when they occur, special provision would have to be made.

The great bulk of transits observed would be covered by the method explained above.

Royal Observatory, Greenwich,
January 10, 1907.

STANDARD STELLAR MAGNITUDES.

EDWARD C. PICKERING.

A simple method of determining the photographic magnitudes of the stars, on a uniform scale, even if they are widely apart, has been in use here for several years. A brief description of it is given in circular 108. Its advantages are that no special apparatus is required, and that the results obtained by it in practice are very satisfactory.

A determination by this method of a large number of standards of photographic magnitude, uniformly distributed throughout the sky, is now in progress. A full description of the method and the resulting magnitudes is in preparation for publication in the Annals. The object of the present publication is to place in the hands of astronomers a means of determining promptly photographic magnitudes on the scale adopted here.

A standard sequence of comparison stars near the North Pole was selected, and their photometric magnitudes determined from a large number of measures with the 4-inch and 12-inch Meridian Photometers. The positions and magnitudes of these stars are given in Table I. The letter designating them is given in the first column, and the Durchmusterung number in the second. All of these stars, except d, f, and g, are contained in the list of stars proposed as standards of magnitude in 1879, Astron. Nach. 95, 29.

Stars a and b are easily recognized as the two brightest stars near the Pole Star. All of the others are shown on Plate I, accompanying Annals, 48, No. I. Their coördinates in millimeters, measured from the left-hand lower corner of that plate, are given in the third column. The precise rectangular coördinates, with the position of the Pole for 1900.0 as an origin, are given in the fourth and fifth columns. Adding 1800″ to these coördinates and dividing by 20 gives nearly the same quantities as those contained in the third column, except that the order of the coördinates is reversed. The sixth column gives the photometric magnitude. Several of these magnitudes depend on many hundred observations, since for the last eight years they have been used as standards, and measured at the beginning and end of each evening's observation with the 12-inch Meridian Photometer. The seventh column gives the adopted photographic magnitudes of these stars. They were derived from measures made by Miss Leland, of 70 photographic plates.

TABLE I.

POLAR SEQUENCE.

Letter	D.M.	48, I.	x	y	Photometric.	Photo-graphic.
			″	″		
a	+88° 4	. .	+5285	+1308	6.43	6.40
b	+88 9	. .	+3894	+2582	7.97	7.98
c	+89 3	131,126	+ 728	+ 860	8.94	8.96
d	+89 29	42, 48	− 860	− 973	10.25	10.21
e	+89 35	55, 67	− 429	− 708	9.84	10.64
f	+89 31	30, 69	− 388	−1221	10.39	11.19
g	. .	67, 86	− 54	− 467	12.22	. .
h	. .	76, 95	+ 134	− 267	12.65	12.70
k	. .	85, 89	+ 12	− 86	13.34	13.27
l	. .	90, 86	− 87	+ 2	13.94	. .

To determine the photographic magnitudes of any stars on this scale, a photograph is first taken of the North Pole, and the standard stars are marked on it. This plate need not be a good one, so long as it shows star h, and perhaps k, and it can be used indefinitely for stars in all parts of the sky. A second plate is then taken of the stars to be measured. Again, it is only necessary that it should show these stars, good images not being essential. The stars whose magnitudes are desired are marked on it, or better, a sequence of stars is selected and marked, each star being slightly brighter than the one next it, and including stars brighter and fainter than any that are to be measured. The third plate is the most important one. It must be taken when the sky is perfectly clear and free from clouds or irregularly distributed haze, and at a time when the given region is at nearly the same altitude as the pole. Under these conditions a photograph of the region is taken in the usual way, and a second exposure of exactly the same length is made upon the pole. It is essential that the images in the two exposures should be so nearly alike that they cannot be distinguished easily. The stars of the polar sequence are now transferred to this photograph by superposing it on the polar plate. The other stars are similarly marked by means of the second plate. The relative brightness of the two sets of images is then measured by any convenient method. That proposed by Bond in 1858, and generally employed elsewhere than at Harvard, consists in measuring the diameters of the images. Other methods are preferred here and are described in the Annals, 26,249. Comparisons are sometimes made with a series of images taken with different exposures, sometimes each star is compared directly with brighter and fainter stars of the standard sequence. The relative brightness of the stars being thus determined upon an arbitrary scale, the absolute magnitude can be determined at once, graphically. A rapid and convenient method is to mark the photographic magnitude opposite each star of the polar sequence, and then estimate directly the magnitudes of the other stars. Thus, a star a little fainter than d 10.2, and much brighter than e, 10.6, would be called 10.3.

It will be noticed that, in Table I, the photometric and photographic magnitudes are nearly the same for all the stars, except e and f. The spectra of these last stars are of the second type, and their color is reddish. According to the measurements made here, they are about 0.8 magnitude brighter photometrically than photographically. This difference would vary with the absorption of the lenses and the character of the plates, and would probably be smaller with a reflector.

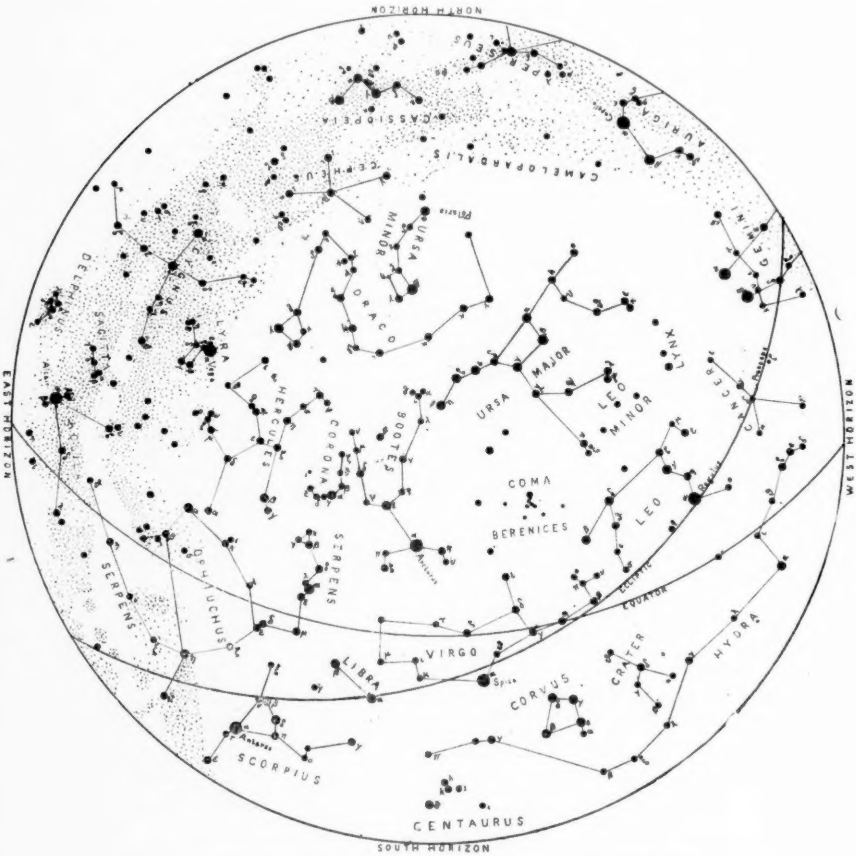
Harvard College Observatory.

Circular No. 125.

PLANET NOTES FOR JUNE, 1907.

H. C. WILSON.

Mercury will be visible during the first half of the month but will come to greatest eastern elongation, 25° 29′ east from the Sun, June 26. The planet will then be evening star, seen almost due west a short time after sunset, but it will



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1, 1907.

not be at all conspicuous and may easily be missed. Mercury will be in conjunction with Neptune June 12 at 8 P. M., C. S. T., when the latter will be 2° 52′ south of the former. On June 15 at 2 P. M. Mercury and Jupiter will be in conunction the former being 1° 41′ north of the latter.

Venus is morning star seen toward the east an hour before sunrise. The phase of the planet is gibbous, about nine tenths of the diameter of the disk being illuminated.

Mars is approaching opposition and may be seen toward the south after midnight. The apparent diameter of the planet will be 19″ on June 1 and 24″ on July 1. Mars is making the turn of the great loop in his path in Sagittarius and will begin to retrograde after June 5.

Jupiter is approaching conjunction with the Sun and so will not be in favorable position for observations during this month.

Saturn will be at quadrature, 90° west from the Sun, June 19, and so may be studied in the morning hours. During this month the Earth will be a little more than two degrees below the plane of the rings; they will show therefore as an almost straight line of light extending out a little way on each side of the planet.

Uranus is in Sagittarius a little way northwest from Mars, and may therefore be seen a little after midnight.

Neptune is nearing conjunction with the Sun and is therefore not visible.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N. °	EMERSION. Washington M.T. h m	Angle f'm N °	Duration. h m
June 23	χ Ophiuchi	4.9	9 33	58	10 21	341	0 48
25	28 Sagittarii	5.6	14 40	42	15 30	309	0 50
28	B.D. −17°6389	6.5	10 38	96	11 40	241	1 02

COMET NOTES.

Comet *b* 1906 (Kopff.)—A telegram received March 24 states that this comet was reobserved by Kopff at Heidelberg 1907 March 21.5909 Gr. M. T. in R. A. $14^h\ 58^m\ 36^s$, Dec. −21° 18′. It is probable that the observation was photographic for the comet was visually very faint last summer.

Comet *a* 1907 (Giacobini.)—This comet is still visible, with a large telescope, but is receding from us and rapidly growing fainter. On April 8 it was for a while so close to the star BD. +3°1205 that the star of the ninth magnitude almost completely hid the comet. An hour later the position of the comet as determined with the aid of our 16-inch telescope was

Apr. 8.6360 Gr. M. T. R.A. $6^h\ 16^m\ 14^s.73$ Dec. +3° 19′ 02″.5

No ephemeris for May is at hand at the present writing.

New Comet *b* 1907 (Mellish). A telegram received April 16 announces the discovery of a new comet by Mellish at Madison, Wisconsin, on the night of April 14. Its position was then about two degrees north of a point midway between Betelgeuse and Procyon. It is described as faint and diffuse and moving rapidly northeast. Position April 14.679 Gr. M.T.; R. A. $6^h\ 40^m$; Dec +8°. Daily motion 3° east and 7° north.

The comet was looked for in region near $7^h\ 4^m$, 22° north on the night of April 16 at Northfield but no comet was in that vicinity which could be seen with the aid of the five-inch finder.

Observations received by telegraph just as we go to press give the position of the comet as follows:

Gr. M. T.	R. A.	Dec.	Observer	Place
Apr. 16.5759	$7^h\ 02^m\ 53^s.5$	+18° 32′ 44″	Rice	Washington
16.6878	7 03 58 .4	+19 03 04	Aitken	Mt. Hamilton

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
June	2	17
	5	5
	7	17
	10	4
	12	16
	15	4
	17	16
	19	4
	22	16
	25	3
	27	15
	30	3

Z Persei

June	3	14
	6	15
	9	16
	12	18
	15	19
	18	20
	21	22
	24	23
	28	1

RX Cephei

June	10	9

Algol

June	2	6
	5	3
	7	23
	10	20
	13	17
	16	14
	19	11
	22	8
	25	4
	28	1
	30	22

RS Cephei

June	10	16
	23	2

R Canis Maj.

June	1	19
	2	23
	4	2
	5	5
	6	8
	7	12
	8	15
	9	18
	10	21
	12	1
	13	4

R Canis Maj.

	d	h
June	14	7
	15	10
	16	14
	17	17
	19	23
	21	3
	22	6
	23	9
	24	13
	25	16
	26	19
	27	22
	29	2
	30	5

Y Camelopardi

June	4	4
	7	12
	10	19
	14	2
	17	10
	20	17
	24	0
	27	8
	30	15

RR Puppis

June	1	19
	8	6
	14	16
	21	2
	27	13

V Puppis

June	2	11
	3	22
	5	9
	6	19
	8	6
	9	17
	11	4
	12	15
	14	2
	15	13
	17	0
	18	11
	19	22
	21	8
	22	19
	24	6
	25	17
	27	4
	28	15
	30	2

X Carinæ

	d	h
June	1	19
	2	21
	3	23
	5	1
	6	3
	7	5
	8	7
	9	9
	10	11
	11	13
	12	15
	13	17
	14	19
	15	21
	16	23
	18	1
	19	3
	20	5
	21	7
	22	9
	23	11
	24	13
	25	14
	26	16
	27	18
	28	20
	29	22

S Cancri

June	4	10
	13	22
	23	10

S Velorum

June	5	19
	11	18
	17	16
	23	14
	29	15

RR Velorum

June	1	22
	3	19
	5	15
	7	12
	9	8
	11	5
	13	1
	14	22
	16	18
	18	15
	20	11
	22	8
	24	4
	26	1

RR Velorum

	d	h
June	27	21
	29	18

SS Carinae

June	1	11
	4	18
	8	2
	11	9
	14	16
	17	23
	21	7
	24	14
	27	21

Z Draconis

June	1	23
	3	7
	4	16
	6	1
	7	9
	8	18
	10	2
	11	11
	12	20
	14	4
	15	13
	16	21
	18	6
	19	14
	20	23
	22	8
	23	16
	25	1
	26	9
	27	18
	29	2
	30	11

δ Libræ

June	2	20
	5	4
	7	12
	9	20
	12	4
	14	12
	16	20
	19	3
	21	11
	23	19
	26	3
	28	11
	30	19

U Coronae

	d	h
June	1	9
	4	20
	8	7
	11	18
	15	5
	18	15
	22	2
	25	13
	29	0

R Arae

June	2	1
	6	11
	10	22
	15	8
	19	18
	24	4
	28	14

U Ophiuchi

June	1	5
	2	1
	2	21
	3	17
	4	14
	5	10
	6	6
	7	2
	7	22
	8	18
	9	14
	10	11
	11	7
	12	3
	12	23
	13	19
	14	15
	15	11
	16	7
	17	4
	18	0
	18	20
	19	16
	20	12
	21	8
	22	4
	23	0
	23	21
	24	17
	25	13
	26	9
	27	5
	28	1
	28	21

Minima of Variable Stars of the Algol Type.—Continued.

U Ophiuchi

	d	h
June	29	18
	30	14

Z Herculis

	d	h
June	2	22
	4	20
	6	22
	8	19
	10	22
	12	19
	14	22
	16	19
	18	22
	20	19
	22	22
	24	19
	26	21
	28	18

RS Sagittarii

	d	h
June	1	16
	4	2
	6	12
	8	22
	11	8
	13	18
	16	4
	18	14
	21	0
	23	10
	25	20
	28	6
	30	16

V Serpentis

	d	h
June	1	3
	4	14
	8	0
	11	11
	14	22
	18	9
	21	20
	25	7
	28	18

RX Herculis

	d	h
June	1	20
	2	17
	3	15
	4	12
June	5	10
	6	7
	7	4
	8	2
	8	23
	9	20
	10	18
	11	15
	12	12
	13	10
	14	7
	15	4
	16	2
	16	23
	17	20
	18	18
	19	15
	20	12
	21	10
	22	7
	23	4
	24	2
	24	23
	25	20
	26	18
	27	15
	28	12
	29	10
	30	7

SX Sagittarii

	d	h
June	1	7
	3	9
	5	11
	7	13
	9	14
	11	16
	13	18
	15	20
	17	22
	20	0
	21	2
	24	3
	26	5
	28	7
	30	9

RR Draconis

	d	h
June	1	19
	4	15
	7	11
	10	7
	13	3
	15	23
	18	19
	21	15
	24	11
	27	7
	30	2

RV Lyræ

	d	h
June	4	5
	7	20
	11	10
	15	0
	18	15
	22	5
	25	20
	29	10

U Sagittæ

	d	h
June	1	20
	5	5
	8	14
	11	23
	15	8
	18	17
	22	2
	25	12
	28	21

SY Cygni

	d	h
June	4	22
	10	23
	16	23
	23	23
	28	23

WW Cygni

	d	h
June	4	5
	7	12
	10	20
	14	4
	17	11
	20	19
	24	2
	27	10
	30	18

SW Cygni

	d	h
June	5	0
	9	14
	14	4
	18	17
	23	7
	27	21

VW Cygni

	d	h
June	4	5
	12	16
	21	2
	29	12

UW Cygni

	d	h
June	3	1
	6	12
	9	23
	13	10
	16	21
	20	8
	23	18
	27	5
	30	16

W Delphini

	d	h
June	4	17
	9	12
	14	8
	19	3
	23	22
	28	18

RR Delphini

	d	h
June	1	5
	5	19
	10	10
	15	0
	19	14
	24	5
	28	19

RV Capricorni

	d	h
June	2	8
	5	14
	8	20
	12	2
	15	8
	18	14
	21	20
	25	2
	28	9

VV Cygni

	d	h
June	1	11
	2	23
	4	10
	5	21
	7	9
	8	20
	10	8
	11	19
	13	7
	14	18
	16	6
	17	17
	19	4
	20	16
	22	3
	23	15
	25	2
	26	14
	28	1
	29	13

U Z Cygni

	d	h
June	5	2

RZ Cassiop.

	d	h
June	1	6
	2	11
	3	16
	4	20
	6	1
	7	6
	8	10
	9	15
	10	20
	12	1
	13	5
	14	10
	15	15
	16	19
	18	0
	19	5
	20	9
	21	14
	22	19
	23	23
	25	4
	26	9
	27	13
	28	18
	29	23

Approximate Magnitudes of Variable Stars on April 1, 1907.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	R. A. 1900. m	Decl. 1900. °	Decl. 1900. ′	Magn.	Name.	R. A. 1900 h	R. A. 1900 m	Decl. 1900 °	Decl. 1900 ′	Magn.
X Androm.	0	10.8	+46	27	<14	W Cassiop.	0	49.0	+58	1	10.5 *i*
T Androm.		17.2	+26	26	9.0 *i*	U Androm.	1	9.8	+40	11	11 *i*
T Cassiop.		17.8	+55	14	9.3 *i*	S Piscium		12.4	+ 8	24	12.5*d*
R Androm.		18.8	+38	1	12.0 *i*	S Cassiop.		12.3	+72	5	11.5*d*
U Cassiop.		40.8	+47	43	<14	RU Androm.		32.8	+38	10	9.5 *i*
RR Androm.		45.9	+33	50	<13	Y Androm.		33.7	+38	50	<14

Approximate Magnitudes of Variable Stars on April 1, 1907—Con.

Name.	R. A. 1900. h	R. A. 1900. m	Decl. 1900. °	Decl. 1900. ′	Magn.	Name.	R.A. 1900. h	R.A. 1900. m	Decl. 1900. °	Decl. 1900. ′	Magn.
X Cassiop.	1	49.8	+58	46	10	RT Hydræ	8	24.7	− 5	59	7.5
U Persei		53.0	+54	20	8.0 *i*	U Cancri		30.0	+19	14	13.5
R Arietis	2	10.4	+24	35	11.5*d*	S Hydrae		48.4	+ 3	27	13.2*d*
W Androm.		11.2	+43	50	11.8 *i*	T Hydrae		50.8	− 8	46	8.2 *i*
Z Cephei		12.8	+81	13	13 6*d*	X Hydrae	9	30.7	−14	15	8.6
o Ceti		14.3	− 3	26	6.0*d*	Y Draconis		31.1	+78	18	12.5 *i*
S Persei		15.7	+58	8	9.6*d*	R Leo. Min.		39.6	+34	58	11.0*d*
RR Cephei		29.4	+80	42	14.0	R Leonis		42.2	+11	54	8.3*d*
R Trianguli		31.0	+33	50	10.2 *i*	V Leonis		54.5	+21	44	13.5*d*
T Arietis		42.8	+17	6	8.5	R Urs. Maj.	10	37.6	+69	18	11.4*d*
W Persei		43.2	+56	34	9.2 *i*	W Leonis		48.4	+14	15	12.5 *i*
U Arietis	3	5.5	+14	25	10.8*d*	S Leonis	11	5.7	+ 6	0	12.0*d*
Y Persei		20.9	+43	50	10.5	R Comae		59.1	+19	20	13.5*d*
R Persei		23.7	+35	20	9.2*d*	R Corvi	12	14.4	−18	42	11.5
Nov. Per. 2		24.4	+43	34	13.0	T Can. Ven.		25.2	+32	3	12.0*d*
T Tauri	4	16.2	+19	18	12	Y Virginis		28.7	− 3	52	10.0
R Tauri		22.8	+ 9	56	13.7*d*	T Urs. Maj.		31.8	+60	2	8.5 *i*
W Tauri		22.2	+15	49	9.6	R Virginis		33.4	+ 7	32	6.5 *i*
S Tauri		23.7	+ 9	44	10.5 *i*	RS Urs. Maj.		34.4	+59	2	13.0 *i*
T Camelop.		30.4	+65	57	8.5*d*	S Urs. Maj.		39.6	+61	38	12.5*d*
X Camelop.		32.6	+74	56	11.5 *i*	S Virginis		39.6	+61	38	12.5*d*
V Tauri		46.2	+17	22	9.4*d*	RV Virginis	13	2.7	−12	28	10.5
R Orionis		53.6	+ 7	59	11.6	V Virginis		22.6	− 2	39	13.0
T Leporis	5	0.6	−22	2	12.0*d*	T Urs. Min.		32.6	+73	56	11.0*d*
R Aurigae		9.2	+53	28	13.7*d*	R Can. Ven.		44.6	+40	2	7.5*d*
S Aurigae		20.5	+34	4	9.0	S Bootis	14	19.5	+54	16	13.4*d*
W Aurigae		20.1	+36	49	11.0	R Camelop.		25.1	+84	17	11.0 *i*
S Orionis		24.1	− 4	46	13.6*d*	R Bootis		32.8	+27	10	10.0 *i*
T Orionis		30.9	− 5	32	10.5 *i*	R Coronae	15	17.3	+31	44	8.0
S Camelop.		30.2	+68	45	9.0 *i*	S Urs. Min.		33.4	+78	58	10.5*d*
RR Tauri		33.3	+26	19	10.5	R Coronae		44.4	+28	28	6.0
U Aurigae		35.6	+31	59	13.0	SS Herculis		28.0	+ 7	3	9.5
Z Tauri		46.7	+15	46	9.5 *i*	W Herculis	16	31.7	+37	32	8.5*d*
U Orionis		49.9	+20	10	8.5 *i*	R Draconis		32.4	+66	58	12.0*d*
V Camelop.		49.4	+74	30	14	S Herculis		47.4	+15	7	8.0
X Aurigae	6	4.4	+50	15	11.5*d*	T Draconis	17	54.8	+58	14	12.5*d*
V Aurigae		16.5	+47	45	9.0 *i*	T Herculis	18	5.3	+31	0	<12
V Monoc.		17.8	− 2	9	10.6*d*	W Draconis		5.4	+65	66	<14
S Lyncis		35.9	+58	0	13.4*d*	X Draconis		6.8	+66	8	9.8 *i*
X Gemin.		40.7	+30	23	11.5*d*	U Draconis	19	9.9	+67	7	10.0 *i*
W Monoc.		47.5	− 7	2	12.2*d*	R Cygni		34.1	+49	58	10.0 *i*
Y Monoc.		51.3	+11	22	11.5*d*	RT Cygni		40.8	+48	32	12.0*d*
X Monoc.		52.4	− 8	56	9.4*d*	χ Cygni		46.7	+32	40	5.6*d*
R Lyncis		53.0	+55	28	12.0*d*	Z Cygni		58.6	+49	46	11. *i*
RS Gemin.		55.2	+30	40	10.4 *i*	S Cygni	20	3.4	+57	42	10.5*d*
V Can. Min.	7	1.5	+ 9	2	<13	RS Cygni		9.8	+38	28	8.0*d*
R Gemin.		1.3	+22	52	12.6 *i*	U Cygni		16.5	+47	35	7.7*d*
R Can. Min.		3.2	+10	11	8.0 *i*	X Cephei	21	3.6	+82	40	9.5*d*
RR Monoc.		12.4	+1	17	<13.5	T Cephei		8.2	+68	5	7.3 *i*
V Gemin.		17.6	+13	17	8.6 *i*	S Cephei		36.5	+78	10	9.5*d*
S Can Min.		27.3	+ 8	32	11.7*d*	RT Pegasi		59.8	+34	38	11 *d*
T Can. Min.		28.4	−20	42	12.5*d*	T Pegasi	22	4.0	+12	3	12 *d*
Z Puppis		28.3	−20	27	8.0 *i*	S Lacertae		24.6	+39	48	9 *d*
U Can. Min.		35.9	+ 8	37	9.0	R Lacertae		38.8	+41	51	13 *d*
S Gemin.		37.0	+23	41	<13.5	V Cassiop.	23	7.4	+59	8	11 *d*
T Gemin.		43.3	+23	59	8.8*d*	Z Cassiop.		39.7	+56	2	8.3
U Puppis		56.1	−12	34	13.0	RR Cassiop.		50.7	+53	8	<13
R Cancri	8	11.0	+12	2	9.6 *i*	Y Cassiop.		58.2	+55	7	9.2*d*
V Cancri		16.0	+17	36	7.5 *i*	R Cassiop.		53.3	+50	50	13.2*d*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whiteside, and Harvard College Observatories.

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop. (−5 19)

	d	h
June	1	12
	16	7

T Monocerotis (−7 23)

	d	h
June	10	7

W Geminorum (−2 22)

	d	h
June	3	23
	11	21
	19	19
	27	17

ζ Geminorum (−5 0)

	d	h
June	11	3
	21	7

V Carinæ (−2 4)

	d	h
June	4	14
	11	7
	8	0
	24	16

T Velorum (−1 10)

	d	h
June	5	2
	9	17
	14	8
	19	0
	23	15
	28	6

W Carinæ (−1 0)

	d	h
June	4	14
	8	23
	13	8
	17	17
	22	2
	26	11
	30	20

S Muscæ (−3 11)

	d	h
June	6	3
	15	19
	25	11

T Crucis (−2 2)

	d	h
June	7	16
	14	10
	21	3
	27	21

R Crucis (−1 10)

	d	h
June	3	3
	8	23
	14	18
	20	14
	26	10

S Crucis (−1 12)

	d	h
June	1	7
	6	0
	10	16
	15	9
	20	1
	24	18
	29	10

W Virginis (−8 5)

	d	h
June	7	3
	24	10

V Centauri (1− 11)

	d	h
June	1	13
	7	1
	12	13
	18	0
	23	12
	29	0

R Triang. Austr. (−1 0)

	d	h
June	2	20
	6	5
	9	14
	13	0
	16	9
	19	18
	23	4
	26	13
	29	22

S Triang. Austr. (−2 2)

	d	h
June	2	17
	9	0
	15	8
	21	16
	28	0

S Normæ (−4 10)

	d	h
June	3	21
	13	15
	23	10

RV Scorpii (−1 10)

	d	h
June	6	20
	12	22
	18	23
	25	1

RV Ophiuchi Minimum

	d	h
June	2	8
	6	1
	9	17
	13	10
	17	2
	20	19
	24	11
	28	4

X Sagittae (−2 22)

	d	h
June	6	12
	13	12
	20	12
	27	13

Y Ophiuchi (−6 5)

	d	h
June	6	23
	24	2

W Sagittarii (−3 0)

	d	h
June	7	21
	15	11
	23	1
	30	16

Y Sagittarii (−2 2)

	d	h
June	6	16
	14	7
	21	21
	29	11

U Sagittarii (−2 23)

	d	h
June	7	5
	13	23
	20	17
	27	10

β Lyrae (−3 2) (−3 7)

	d	h
June	4	16
	11	8
	17	14
	24	6
	30	12

κ Pavonis (−4 7)

	d	h
June	2	15
	11	17
	20	20
	29	22

U Aquilae (−2 4)

	d	h
June	8	0
	15	1
	22	1
	29	2

XZ Cygni Period 11^h

	d	h
June	1	22
	2	20
	3	19
	4	17
	5	15
	6	14
	7	12
	8	11
	9	9
	10	7
	11	6
	12	4
	13	3
	14	1
	14	23
	15	22
	16	20
	17	19
	18	17
	19	15
	20	14
	21	12
	22	11
	23	9
	24	7
	25	6
	26	4
	27	2
	28	1
	28	23
	29	22
	30	20

U Vulpeculae (−2 3)

	d	h
June	8	11
	16	10
	24	10

SU Cygni (−1 7)

	d	h
June	2	6
	6	3
	9	23
	13	9
	17	16
	21	12
	25	8
	29	5

η Aquilae (−2 6)

	d	h
June	6	16
	13	20
	21	0
	28	4

S Sagittae (−3 10)

	d	h
June	8	12
	16	21
	25	6

V Vulpeculae Minimum

	d	h
June	7	1

X Cygni (−6 19)

	d	h
June	1	6
	17	15

T Vulpeculae (−1 10)

	d	h
June	4	9
	8	20
	13	6
	17	17
	22	3
	26	14

TX Cygni

	d	h
June	8	1
	22	19

WZ Cygni Period 14^h. Minimum

	d	h
June	2	3
	3	7
	4	11
	5	15
	6	19
	7	23
	9	3
	10	7
	11	11
	12	15
	13	19
	14	23
	16	3
	17	8
	18	12
	19	15
	20	20
	22	0
	23	4
	24	8
	25	12
	26	16
	27	20
	29	0
	30	4

RV Capricorni Period $10^h.8$

	d	h
June	1	17
	2	14
	3	12
	4	9
	5	7
	6	4
	7	2
	7	23
	8	21
	9	18
	10	16
	11	13
	12	11
	13	8
	14	6
	15	3
	16	1

Maxima of Variable Stars of the Short Period not of Algol Type.
Continued.

RV Capricorni

	d	h
June	16	22
	17	20
	18	17
	19	15
	20	12
	21	10
	22	7
	23	5
	24	2
	25	0
	25	21
	26	18

RV Capricorni

	d	h
June	27	16
	28	13
	29	11
	30	8

VY Cygni

	d	h
	(−2	2)
June	2	3
	10	0
	18	21
	26	17

VZ Cygni

	d	h
	(−2	12)
	(−3	6)
June	4	6
	9	6
	14	0
	19	0
	23	17
	28	17

δ Cephei

	d	h
	(−1	10)
June	6	7

δ Cephei

	d	h
June	11	16
	17	1
	22	10
	27	19

V Lacertæ

	d	h
	(−1	17)
June	1	5
	6	5
	11	5
	16	4

V Lacertæ

	h	d
June	21	4
	26	3

88.1906 Lacertæ Minimum

June	6	18
	12	5
	17	15
	23	2
	28	12

Variable 156.1906 Persei.—The new variable discovered by Millosevich on November 6, 1906 and estimated then to be of magnitude 8.5 has continued to decrease in brilliancy. In *A.N.* 4158 Professor Millosevich gives the following estimates:

Date	Mag.	Date	Mag.
1906 Dec. 14	9.7	1907 Jan. 12	10.4
18	9.7	20	10.6
26	10.0	28	11.1
1907 Jan. 8	10.1	Feb. 12	11.7

Eighteen New Variable Stars.—The eighteen new variable stars discovered at Harvard College Observatory and announced in Circular No. 124 have received the numbers 5 to 22.1907.

Variable Star 10.1907 Draconis.—This is Harvard 1310, one of the eighteen referred to in the above note (See also our March number, p. 185). In *A.N.* 4159 Messrs Müller and Kempf of the Potsdam Observatory state that this star had already been announced as variable in Band 16 of the Potsdam Publications. They also give a large number of observations made in the years 1904-6, which seem to show that the variation is irregular, the visual range of magnitude being between 6.0 and 7.0 while Pickering gives the photographic range 8.5 and 10.5.

New Variable 23.1907 Lacertæ. In *A. N.* 4159 Professor W. Ceraski announces a new variable discovered by Mme. L. Ceraski on the Moscow photographs. The star is BD. + 50°358 1 (Mag. 9.0), and its position is

1855	$\alpha = 22^h\ 03^m\ 30^s.10$	$\delta = +50°\ 20'\ 08''.9$
1900	22 05 13 .13	+50 33 18 .8

The period is undetermined but is short, probably only a few days, and the range of variation is from about 8.5 to 9.2 magnitude.

New Variable 24.1907 Monocerotis.—Another new variable is announced by Professor Ceraski in *A.N.* 4161. This also was discovered by Mme. L. Ceraski on the Moscow photographs. It is the star BD. + 8°1402 (Mag 9.0), and its position is

1855	$\alpha = 6^h\ 26^m\ 50^s.48$	$\delta = +\ 8°\ 56'\ 01''.9$
1900	6 29 18 .10	+ 8 54 11 .7

It is possibly of the Algol type and the range of its variation from 9.0 to about 10.5.

Variable Star BD. + 37°811. From a private letter by J. Miller Barr of St. Catherine's, Ontario we have some interesting data about the new variable star B. D. + 37°811 in the constellation of Perseus which he has been observing since January 5, 1907. He says: "Its approximate place

Right ascension, 3^h $34^m.6$
Declination + 37° 16′

It is rated in the Harvard Photometric Durchmusterung, as magnitude, 5.39; in the Draper Catalogue its photometric magnitude is given as 5.52; spectrum A.

This star is exceptionally interesting, the period as indicated by the writer's observations, being the shortest hitherto found. Observations made on individual nights show a distinct and unmistakable periodicity: the interval between successive maxima and minima being only about 58 minutes. The approximate range is 0.35 of a magnitude. The light curve appears to be nearly symmetrical, so that the interval from maximum to minimum is scarcely one half hour.

My comparison stars for this variable are B. D. +37°742, mag. 5.50; +39°811 mag. 5.83; 34°768 mag. 5.48 as rated in the Harvard Durchmusterung.

Great care has been exercised in making the comparisons, and the results are believed to be practically free from systematic error."

Mr. Barr hopes to send us fuller data in an extended description of this star later.

An Algol Minimum.—In *A.N.* 4161 Mr. G. Van Biesbrock states that a minimum of Algol observed on March 4, 1907 indicates a correction of $-0^h\ 57^m$ to Hartwig's ephemeris. The tables of minima of Algol from which those given in POPULAR ASTRONOMY are prepared agree with those of Hartwig and therefore are subject to the same correction, although we attempt to give only the nearest hour of the predicted minimum.

Two New Variables with Very Rapid Light Changes.—These are numbered 3.1907 Herculis and 4.1907 Vulpeculæ and are announced by Mr. Jules Baillaud in *Comptes Rendus* 144 p. 250. Their positions for 1900 are

	α	δ	mag.
3.1907 Herculis	$16^h\ 54^m\ 11^s$	+21° 42′ 00.″	12.7 — 14.5
4.1907 Vulpeculæ	19 00 08	+24 40 16	13.6 — 14.5

The changes of magnitude indicated occur in the intervals $1^h\ 06^m$ and of $1^h\ 17^m$ respectively.

GENERAL NOTES.

Study and Observation of the Planets. In common with other publications like this, we have had little to say about the study and observation of the planets, not because there is little or nothing to say, but because many other things have claimed our attention too fully for time or space for this most interesting line of astronomical work. The fact that, for some time past, *The Observatory* (English) has had a continued article from month to month, by the pen of an able writer on astronomical themes has brought this matter forcibly to mind and it is our purpose to supply for our readers something of this kind in the near future.

Another thought about such matter is the possibility and even the probability that such a course, if rightly pursued, might stimulate observation of the planets and their satellites, in various ways, that would be useful to astronomy. There is plenty of opportunity for useful work in this delightful field.

Great Solar Protuberance, Aug. 30, 1905. We have chosen for our frontispiece, a copy of the reproduction of the original negative in the same size, of a great protuberance, seen on the east limb of the Sun at the total eclipse of August 30, 1905. The photograph was taken by the Hamburg Expedition that went to a point Souk Ahras in Algeria, Africa. The exposure was by a telescope of 20 meters in length, and the time was four seconds. The account of this expedition was prepared under the direction of Professor Dr. Schorr, the director of the Observatory at Hamburg, Germany.

Publications of the Astrophysical Observatory at Potsdam. The seventeenth volume of the Potsdam Publications, which has recently come to hand contains a general catalogue, giving the photometric magnitude of all the stars in the northern hemisphere down to the magnitude 7.5 of the Bonn Durchmusterung. Glancing over the column of photometric magnitudes one notices a surprisingly large number for which the measured magnitude comes out fainter than 8.0 or even 9.0. The colors of the stars are recorded on the scale of W = white, GW = yellowish white, WG = whitish yellow, G = yellow, RG = reddish yellow, GR = yellowish red and R = red. The total number of stars for which the measures are given is 14199.

The Madras Observatory. Professor David Todd, F.S.A., sends us these interesting facts concerning the Observatory, quoted from an address by Sir James Thomson, LL.D., for thirty-five years President in India, published in the *Journal of the Society of Arts* (London) for March 29, 1907:—

'Nungumbankum, described in 1708 as under Egmore, is mostly remarkable as containing the Observatory and many of the fine old garden houses. The Observatory dates back to 1792, and is due to William Petrie, Sir Charles Oakeley, and the Company. It is chiefly occupied now with meteorological work and keeping time for India, the Observatory for Solar Physics having been transferred to Kodikanal, on the Pulney Hills.'

Cause of Earthquakes and Other Phenomena Connected with the Physics of the Earth. Dr. T. J. J. See, Professor of Mathematics, U. S. Navy, in charge of the Naval Observatory, Mare Island, California, has prepared and published in the Proceedings of the Am. Phil. Soc. Vol xlv, 1906 an extended article on "The Cause of Earthquakes, Mountain Formations, and Kindred Phenomena connected with the physics of the Earth. This interesting paper claims that "the dynamical cause of earthquakes and volcanoes probably depends upon the explosive power of steam formed within, or just beneath, the heated rocks of the Earth's crust, chiefly by the leakage of the ocean beds."

It is further said that "the internal temperature of the Earth is extremely high, with heated rocks quite near the surface, while the crust is fractured and leaky everywhere, and especially where the depth of the sea is greatest. The sea covers three-fourths of the Earth's surface, and 'earthquakes are found to be most violent where the sea is deepest, and volcanoes most numerous on the adjacent shores.' Could then anything be more probable, than to suppose that both these great natural phenomena depend simply and wholly upon the explosive power of steam which has developed in the heated rock of the Earth's crust?"

Professor See presents the views of some noted physicists, shows the weakness of some late theories, enters fully in the discussion of many related topics and presents a full analysis of the present physical conditions that are claiming the attention of scholars very largely. The paper will interest scientific readers generally.

Transactions of the Wisconsin Academy of Sciences, Arts and Letters. Vol. xv, part 1., for 1904 is an interesting publication of 272 pages. It covers a wide range of subjects, is neatly printed and illustrated with eight plates. Though bearing a date of 1905, the volume has just come to hand.

The Constitution of the Ring of the Minor Planets. Professor P. Stroobaut, astronomer in the Belgian Observatory and Professor in the University of Brussels has recently published a paper on the constitution of the ring of the minor planets. The first point is a brief sketch of the discovery of the first and the larger of the minor planets connected with some of those discovered since and recently that have striking features from which the author gets important data for a careful discussion that is well worth the perusal of any student of astronomy that can read the French and understand the mathematics. The tabular part of the paper is full and especially helpful in giving exactness to the points presented.

We will try to get an abstract of this paper that our readers may have more information about it than we can possibly give in the compass of this brief note.

A Comet to strike the Earth. From the letters we have received, we imagine something of the interest that has been awakened in the minds of some who may have heard of the catastrophe predicted by some one who claims that a comet is to strike the Earth with all the dire consequences that may possibly result from such a collision.

Of course it is possible that a comet might strike the Earth in a head-on collision. But without figuring out the probability of such an event, it is safe to say that the probability against it is at least many millions to one. If there should be a collision of the Earth with the nucleus of a comet that was large there would certainly be trouble and probably a good deal of it. For it is pretty certain that the nucleus of some large comets contain solid matter that probably amounts to hundreds of tons. One can not imagine the effect of a direct collision of two such heavenly bodies moving with the velocities of the Earth and a comet when such bodies are within ninety three millions of miles from the Sun. The Earth is moving at the rate of about eighteen and one half miles per second while the motion of the comet would not be far from twenty six miles per second. But their relative velocities at any point of meeting would be less than these figures but great enough to cause all the trouble anticipated by those who know of the mechanics of the solar system. If the Earth should pass through the tail of a comet, large or small, probably no appreciable effect would be realized. For the tail of a comet is one of the most rare and attenuated parts of a celestial body known to exist. But for the light that probably comes from its gaseous condition, it is questionable if it could even be seen visually.

This story that is going the rounds in the daily prints is undoubtedly a fake. What has just been said is to answer late queries that have come to us, rather than to pay attention to any one of that annual crop of "fakes" that must be expected to grow in good scientific soil.

Longitude of the Observatory at the University of Minnesota. We have received a circular from Professor F. P. Leavenworth of the Observatory at the University of Minnesota, giving an acconnt of the determination of the difference of longitude between the Washburn Observatory of the University of Wisconsin and the Observatory of the University of Minnesota by Geo. C. Comstock and F. R. Leavenworth. The observing list contained twelve stars: the exchange of signals was made midway in the list, and signals from the two clocks at the different observatories were compared by telegraph in the usual way. The personal equations of the two observers were investigated in two ways. First the relative personal equation was obtained by observations with the Minneapolis Transit instrument, and, secondly, by the use of the Goodsell Observatory Personal Equation Machine.

The observations for longitude were made on five different nights between July 19 and July 31 1895.

According to a letter from the Superintendent of the Coast and Geodetic Survey, the longitude of one of their stations on the campus of the University of Minnesota was determined by them in 1891.

From this value, an accurate determination of the longitude from Greenwich of the Observatory of the University of Minnesota and of the Washburn Observatory becomes possible

	h	m	s
Longitude of Coast Survey Pier	6	12	56.845
Minneapolis Transit from Coast Survey Pier			+ 0.196
Longitude of Observatory of University of Minn.	6	12	57.041
Difference Longitude, Minneapolis Madison		15	19.134
Longitude of Bamburg Transit of Washburn	5	57	37.907
Meridian Circle West Bamburg Transit			+ 0.178
Longitude of Washburn Meridian Circle	5	57	38.085
The longitude of the Meridian Circle of Washburn Observatory from the earlier observations is	5	57	38.83

This information came to hand only very recently. It should have been published long ago.

Studies of the Thermodynamics of the Atmosphere. Professor Frank H. Bigelow concludes a full mathematical paper in the October number of the *Weather Review*, with title "Studies of the Thermodynamics of the Atmosphere." At the end of the article appears a small table making a comparison of the probable sustaining vertical velocities for hailstones large and small.

Height	Probable sustaining velocity For common Hail stones	For large Hail stones
Meters	M. per S.	M. per S.
0	12.8	25.6
1000	13.6	27.2
2000	14.4	28.8
3000	15.3	30.6
4000	16.2	32.4
5000	17.2	34.4
6000	18.3	36.6
7000	19.3	38.6
8000	20.5	41.0

Lantern Projection Distances. The usual published tables of size of disk for a given distance from screen with a three-inch slide for different focus lenses in projection are perhaps near enough for all ordinary exhibition purposes but not sufficiently so for accurate projection calculations. The tables give a constant ratio between disk and distance the same as a pinhole lens would give, whereas the conjugate focus of an objective naturally increases the disk, greater in proportion than the distance calls for, amounting to nearly eighteen inches or a twenty-one foot disk with a half size objective, as in the table herewith, from actual experiments by the writer on the 73-foot floor of the Portage armory, February 5, 1907 through the courtesy of Company F, third regiment, some of the members of which kindly assisted with the measurements. The alternating ten ampere arc lamp was used in the lantern. The objective was half size, nine and one-fourth inches equivalent solar focus, and according to the one-fourth equal image distance, the slide, a hymn, words and music, full field, having a three-inch exact mat, focussing sharp at half way from center to edge.

As a three-inch slide is a rarity, and two and seven-eighths inch horizontal being the almost universal width, a column is also given for disks from this width, which ranges tolerably close enough to the usual tables for ordinary purposes. The ratio of slide to focus should be the same as disk to distance and is closely.

TABLE OF LANTERN PROJECTION DISTANCES.

Screen to Objective Diaphragm	Lesser Conjugate Focus	Diameter of Disk	Same from 2⅞″ slide	Times enlargement	Ratio 3″ slide to Conjugate Focus	Disk per Published Tables
Ft.	Inches	Ft. In.	Ft. In.			
10	10.00	3.00	2.10½	12	3.333	3.00
20	9.60	6.03	6.00	25	3.200	6.00
30	9.47	9.06	9.01½	38	3.158	9.00
40	9.41	12.09	12.03	51	3.137	12.00
50	9.37	16.00	15.04	64	3.125	15.00
60	9.35	19.03	18.05½	77	3.117	18.00
70	9.33	22.06	21.07	90	3.110	21.00

H. W. Griggs.

Portage, Wisconsin, February 16, 1907.

Perturbations of Halley's Comet. By the No. 3. Jan. number of *Monthly Notices* of the Royal Astronomical Society, it is noticed that P. H. Cowell and A. C. D. Crommelin are at work on the perturbations of Halley's Comet. It will be remembered that Pontecoulant's date for the next perihelion passage of this comet is 1910 May 13, which is thought to be approximately correct.

The above named astronomers have already done some preliminary work by abbreviated methods, and they conclude that May 1910 is correct within a month for the next perihelion passage. The actual result thus obtained was a fortnight earlier than that obtained by Pontecoulant but they lay no stress on this difference.

They are now investigating these perturbations more accurately, dividing the orbit into 180 portions, and they include the perturbing effect of Venus, Earth and Neptune, which Pontecoulant did not consider. The computations of these astronomers already confirm the suspicion that Pontecoulant's value of eccentricity in 1910 is in error. It is about the same as at last return, 0.59 instead of 0.68 as he gave it. This fact will considerably modify the point at which the meteors accompanying the comet would intersect the Earth's orbit.

Astronomers will look for the results of the work of these two well-known computers with much interest.

Sixth Report of the Variable Star Section.—This report of the Variable Star section of the British Astronomical Association is given for the years 1900-1904 by the Director—Col. E. E. Marckwick, C. B., F. R. A. S. It is a memoir of 140 pages and fourteen large plates, and contains observations of twenty-six "long period" and two "irregular" variables. The observations were made by twenty-one different persons but have been brought together, reduced and plotted by the Director of the section and Mr. C.L. Brook. This furnishes an excellent example of what may be done by concerted effort on the part of a number of amateur observers. Concerning it Col. Marckwick says:

"Experience shows that very reliable results as to light-curves of variables can be deduced from the work of several observers acting in concert. It is true that in the precise matter of "magnitude," observers will often produce different results, even when observing practically simultaneously. This may be due to the idiosyncrasy of the observer, to differing weather conditions, and to other causes. But even in the case of the largest divergence in light-estimates, if the curves from each observer's observations are separately plotted, it is seen they generally run fairly parallel to one another, so that the mean curve of the whole will in all probability be a very fair approximation to the truth."

On the Errors of a Photographed Réseau. In *Monthly Notices*, No. 3, January 1907, Astronomer Royal W. H. M. Christie, A. S. Eddington and C. Davidson present an investigation of the errors of a photographed réseau which was used in the measurement of the photographic plates of Eros, 1900-1901. This is a new and a very interesting problem in the use of the photographic method in the work of fundamental measurements. How the measurements of these errors was made and the results obtained are matters of peculiar interest now, because the degree of accuracy of the photographic method for fundamental work is still in question. The mathematical tests that have been applied to the method during the last two years have been helpful and critical, but not yet thoroughly conclusive; for good authority is not yet in agreement sufficiently general to rank the method as certainly the best of all.

In the study of the errors of a photographic réseau the Astronomer Royal divided the work into three parts: (1) A more accurate measurement of the errors of certain lines numbered 13, 14, 15, on the silver réseau. (2) Measurement of the systematic differences between prints of the réseau and the réseau itself. (3) Examination of the straightness of the réseau lines.

We were extremely glad to look into this important study of the sources of possible errors in the measurement of photographic plates, because we believe there is much in the photographic plate of substantial worth when the astronomer is able to get out of it all there is in it. It seems to us that the Astronomer Royal is attacking the problem in the right way so far as the mathematics is concerned. What more he or others may do when these important points are satisfied remains yet to be seen.

This work does not at all stand in way of what the physicist may do in delving into, and bringing out of, the exposure of the sensitive plate what is apparently hidden in its most wonderful film. We have seen some work in this line that was simply marvelous, even beyond all thought that had before entered our minds. The glorious days of celestial photography are fast opening upon a world of useful science.

Motion of Vapors in Sunspots in the Line of Sight. It has been regarded by good authority in the astronomy of the Sun, that the motion of the metallic vapors in sunspots was generally downward or inward through the umbra of the spot and upward or outward through the outer portions of the penumbra. Professors Hale, and Adams refer to this matter in the March number of the *Astrophysical Journal*, page 86, in the following language:

The importance of the question of the motion in the line of sight of the spot vapors as bearing on any theory of spot structure, is of course, very great, and has been kept in mind in the investigation of our observational material. In the method which we have adopted of photographing spot spectra it is necessary to make the exposures on spot and disk separately, occulting one while the other is being photographed. For this purpose an occulting bar is moved across the slit by means of a rack and pinion, as in most stellar spectrographs. Accordingly, the danger of errors arising from instrumental sources should not be great.

The study of the plates has led to the conclusion that there is as a rule very little motion in spot umbrae. Out of eighty plates of eleven spots only two gave any reasonably certain displacements of the spot lines, and even in these two cases the values were close to the limit of accuracy of the measures. In both instances the motion was directed downward, and amounted to about 0.2 km a second. In one case, moreover, the motion was certainly temporary, since plates of the same spot taken on the following day gave no displacements whatever. The general conclusion, then, seems to be justified that the vapors forming the umbra of a well-developed spot are normally nearly at rest, with perhaps some presumption of a slow downward drift. This result is an agreement with that found by Mitchell from the study of a large number of spots during 1904-5. He says: "Line-shifts in the spot spectrum, with the exception of those due to hydrogen, are very rare."

Studies in Sensitometry. Robert J. Wallace of Yerkes Observatory, has published a most useful article in the March *Astrophysical Journal*, bearing the title of studies in sensitometry dealing especially with the points of daylight sensitometry of photographic plates, and a suggested standard dispersion piece. The brief summary of the article as given by Mr. Wallace is as follows:—

1. The advancement of a replica-grating as a standard dispersion-piece, together with a simple form of spectrograph suited to its use.

2. A suggested method of daylight sensitometry (making use, as far as possible, of the laws discovered by Hurter and Driffield), of which the following is a résumé:

a) Exposure of one $2 \times 4\frac{1}{4}$ plate scored down the back, but not broken through, together with one $2 \times 4\frac{1}{4}$ Seed "27" plate, for, say, two minutes, in the sector-disk machine.

b) The scored plate is broken through into two secondary slips, and all four plates are now developed (preferably together) with a constant developer, for a constant length of time, and at a constant temperature, with the exception of one of the secondary slips which remains in the developer for exactly double that of the others.

c) Measurement of the density strips and extraction of γ, t_{γ_n} and latitude.

d) Exposure of a second pair of $2 \times 4\frac{1}{4}$ plates and development for the time necessary to obtain equal amounts of development action as found from *d*, retaining composition of developer and temperature as constants. Measurement of same and extraction of speed-ratio.

e) Exposure of $3\frac{1}{4} \times 4\frac{1}{4}$ plate to a series of eight exposures in the spectrograph varying from two seconds to eight minutes, and two further exposures on the same plate with the collimator wedge in position and through the ammonium picrate screen.

f) Measurement of selected spectrum for quantitative color estimation.

Prague Observatory. We were recently favored by Dr. L. Weinike of Prague Observatory with a fine volume of astronomical observations, made at the Observatory during the years 1900-1904. It is a volume of general work covering many different branches of astronomical work.

Observation of Double Stars at Washburn Observatory. Professor George C. Comstock has recently published part 3 of Vol. X of the publications of the Washburn Observatory, Madison, Wisconsin. This volume contains the individual measure of about 150 important double stars, made during the years 1897-1906. The data are all so explicit that workers in this branch may have satisfaction in using it.

Vacant Regions in the Sky is the title of an article which was published in the December number of this Journal. It was illustrated by three fine plates showing well some marked vacancies in stellar regions of the sky by E. E. Barnard of Yerkes Observotory with his new photographic camera on Mount Wilson in California. This article and the three plates are reproduced in the March number of the Bulletin of the Astronomical Society of Belgium. If a finer screen had been used in the reproduction we think a better effect on the plates would have been secured. On the whole the copying was pretty well done.

Dr. A. G. Sivaslian of Anatolia College, Marsovan, Turkey, is about to publish a text-book on Astronomy. It is to be in both Turkish and English, and to be fully illustrated by the best half-tone cuts of modern style. He has asked that the printing of all the cuts which are to be used as plates in the new book be printed on the presses of the *Northfield News* Office where the work of this publication is done. If we mistake not Dr. Sivaslian's new book will mark an epoch both in modern bookmaking and in the study of Astronomy in the far East.

Dr. Sivaslian was the first graduate in the post course of three years in Astronomy and Mathematics given by Carleton College in 1899 and later.

Osborne's Calculus. It is gratifying to all teachers of the calculus to know that the best writers on this branch of mathematics, are keeping their text-books well up to date.

We have before us a revised edition of the Differential and Integral Calculus by George A. Osborne who is Professor of Mathematics in the Massachusetts Institute of Technology. It is a book of 388 pages, and published by Messrs. D. C. Heath & Co., of Boston.

Professor Osborne's original work was a text-book of the Calculus based on the method of limits that aimed to be within the grasp of students of average mathematical ability, and yet it contained all that was essential to a working knowledge of the subject.

In the revision before us, the same object has been kept in view. Most of the text has been re-written, the demonstrations revised and for the most part new exercises have been substituted for the old. There has also been some rearrangement of subjects in what the author deems a more natural order.

In chapter second of the Differential Calculus, illustrations of the "derivative" have been introduced, and such are also found in the following chapters. It is well to give careful attention to the meaning and the correct application of the derivative in the beginning of this important branch. In our experience, we find that the average student needs a thorough drill in the meaning of the derivative as distinguished from the differential, and especially when he takes the step on passing from the increment to its limit, which is a differential of infinitesimal kind, or a state of the function where the law of operation applies and sits with exactness and absolute rigor.

In chapter VII there is the study of series that is entirely new. We also notice some changes in the early part of the Integral Calculus.

The important feature that we like to see in this revision is the fact that the exercises are largely made up of applications to Mechanics and Physics. The thinking student is often asking to what uses can the calculus be applied. When the exercises and the problems bring these matters to his attention in this practical way, he will readily see the uses of the study more plainly than any instructor could explain to him in verbal way.

This revision seems to fulfill the needs of the present time admirably. It is heartily commended.

The Time Service in the Dominion Observatory, Canada is written up in the second number of the new *Journal of the Royal Astronomical Society of Canada*. The description of this service is quite complete going into all the important details about the clocks, the electrical apparatus, connection with outside telegraph lines, grades of clocks, time-ball service and other common uses of the electrically controlled clocks.

The working parts of the apparatus for carrying the signals from the secondary clocks to the ordinary telegraph lines is fully illustrated by cuts which give a definite idea of the plan chosen for the time service and how it works. To all interested in this kind of astronomical work, the details of the plan will be interesting, not so much because the methods are new, but rather because all is so well shown that any one may easily understand it.

The fact that those in charge of the work feel the necessity of keeping fine clocks under a nearly constant temperature to get from them a steady and a reliable service is noteworthy.

We notice that the dead-beat escapement is used in some of the standard clocks in this service. A hint in regard to this kind of escapement may be of service. The rate of this kind of a clock is generally under good conditions fairly steady. But those in charge should keep close watch of it and check its work often lest it "jump" a second or more without the slightest notice to the timekeeper in regard to the cause for such a change.

Errata. Page 217, second paragraph and footnote read Almagest for Amalgest. Page 220 in second footnote for spirit of demon read spirit or demon. Page 220, third footnote insert Jan. before 1898. One of these errors was in the copy.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with January 1906, the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, Canada and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers are still on sale at the old prices, $2.50 and 30 cents, respectively.

Wm. W. Payne,
Northfield, Minn., U. S. A.